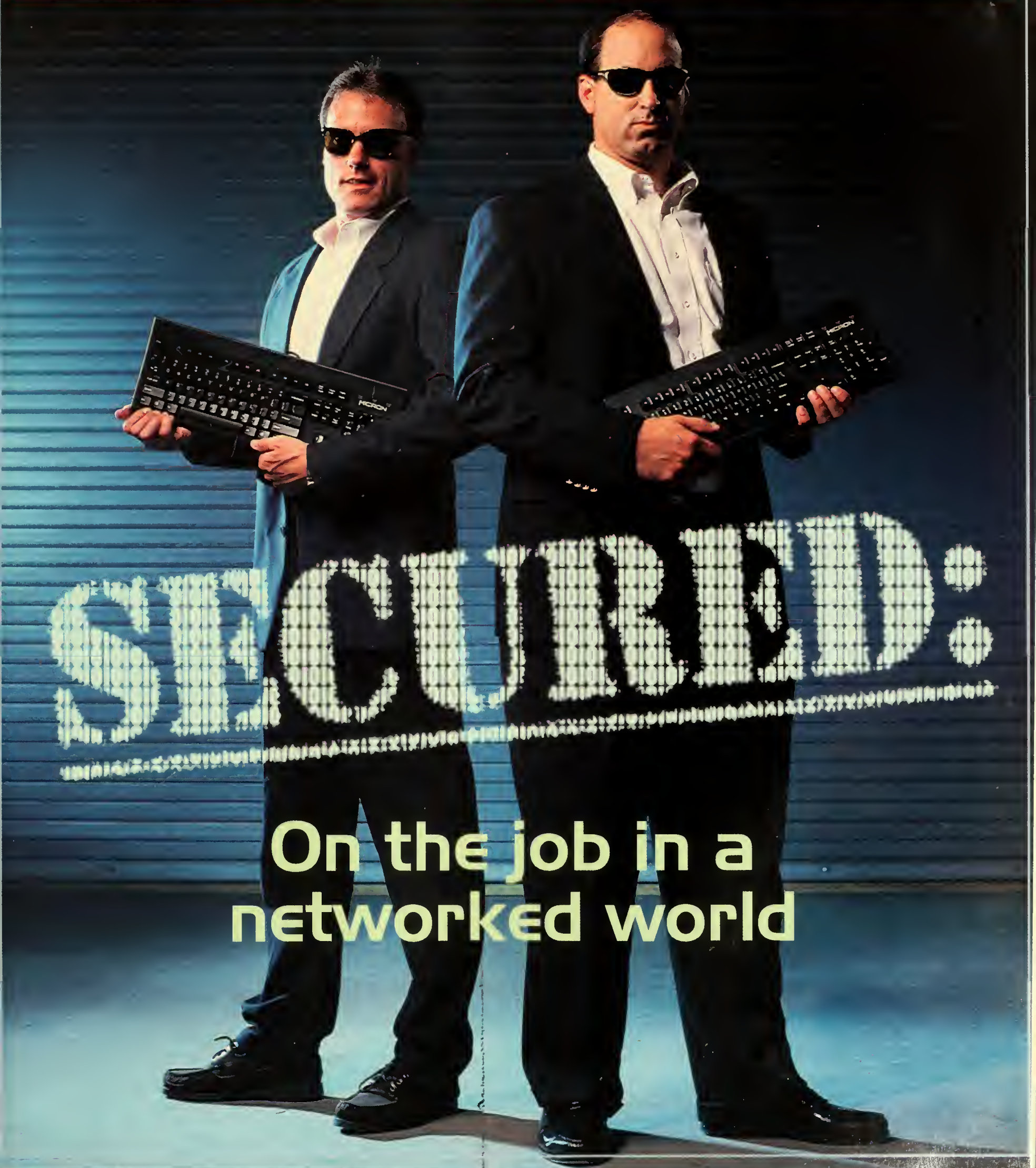
◆ A VISION OF NASA'S FUTURE ◆ THE STATE OF THE UNIVERSITY ◆ FOUR HIGHWAYMEN

WPI JOURNAL

SUMMER 1998



On the job in a networked world

Janet and Ray Forkey '40

Home: Tequesta, Fla. and Worcester, Mass.
Planned Gift: Charitable Lead Trust

— On the Game of Golf —

"People from all over the world share a connection in loving this game," says Ray. "Sure, it's competitive—that's a good part of the fun—but I also enjoy the camaraderie that makes playing the game a wonderful experience wherever we go." His love of golf has led Ray to serve on the boards of several senior golf organizations; he's been president of two. "These experiences have allowed me to give something back to the sport that's given me so much." Through his volunteer work, Ray and Janet have played more than 100 national and international courses, and Ray has been champion of four clubs, winning 11 titles at the Worcester Country Club. "I've shot my age well over 150 times since turning 72," Ray says, "and I hope to keep on swinging."

— On Planned Giving at WPI —

"Janet and I wanted to make a significant contribution to reflect our gratitude for my WPI experiences. I've always thought giving appreciated stock is an ideal way to contribute, but we also needed to find a way to reduce the taxable portion of our estate without detrimentally affecting our heirs. The Charitable Lead Trust was a good solution. It will generate gifts of stock directly to WPI for the next 10 years, then whatever is left in the trust will go to our family at a time when they can use it. We receive a significant estate tax deduction and WPI gets a gift it can use right away. That adds up to a 'hole-in-one' for the Forkey family and for WPI."

The current economic climate may be especially favorable for establishing lead trusts. To learn more about this or other planned giving opportunities at WPI, please contact Liz Siladi, Director of Planned Giving, at 1-888-WPI-GIFT.

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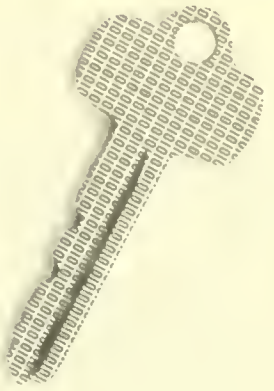

Secured: A Special Focus

Who Goes There? A group of WPI alumni are out to cure the Net's identity crisis, *by Elizabeth Walker;* **Keys to the Future** Professor Christof Paar works to make on-line security faster and safer, *by Michael W. Dorsey;* **His Life's Opus** Opus Telecom keeps tabs on the vast market for pre-paid phone calls, *by Elizabeth Walker.*

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NASA's bold plans may hinge on a new vision for technological education.

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Past is prologue as WPI's president sets the stage for a "great leap forward."

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How a gift of a music box grew into a lifetime of collecting and giving.

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Front Cover: Go ahead, make their day! Would-be data thieves and on-line impostors are being stopped in their tracks by software and hardware emerging from the minds of cryptographers and engineers like Jeff Breed '85 and Joe Vignaly '82 of GTE CyberTrust Solutions. Story on page 4. Photo by Jonathan Kannair. Back Cover: In the next 25 years, astronauts may depart from the International Space Station for Mars, near-Earth asteroids and other celestial destinations, says NASA Administrator Dan Goldin. Story on page 16. Photo courtesy NASA.

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Celebrating Five Years of Projects in Costa Rica

WPI made its first forays into global technological education more than 25 years ago with university exchange programs in London and Zurich. Its first overseas center for student project work opened 11 years ago in London. Since then, programs have been established in cities around the globe. The list of WPI's global project sites will expand over the next 18 months with the addition of Boston, Copenhagen, Melbourne, and Kariba, Zimbabwe.

From left, Malinda Danforth, Jocelyn Songer and Park Hays completed their project in Spanish.

As the University's Global Perspective Program matures, some project sites are reaching significant anniversaries. Last year, the London Project Center celebrated its first 10 years. A gala event is being organized for the summer of 1999 to note the 10th anniversary of the Venice Project Center. In July, WPI observed five years of project work in Costa Rica with a party in San Jose. Guests included students completing projects in Costa Rica, alumni, representatives of sponsoring corporations, museums and agencies, and prospective WPI students and their parents. Provost John F. Carney III gave the welcome address. Susan Vernon-Gerstenfeld, who directs the Costa Rica, Puerto Rico and Washington, D.C., project centers, discussed the history of the center and the range and focus of student projects there.

Since the center was established in 1993, 69 undergraduates have completed 24 Interactive Qualifying Projects there. Topics include reforestation, energy and water conservation, computerization, and tourism. "WPI students are doing valuable work within the cultural context of the country," says Vernon-Gerstenfeld. "Many of the students who complete IQPs in Costa Rica have completed their Humanities Sufficiencies in Spanish and write and present their work in that language. It's the perfect marriage of these two degree requirements."

The following projects were completed in Costa Rica this summer:

Market Analysis for a Museum

The National Museum of Costa Rico is planning to move its offices to a new building to provide space for a new café, new exhibits and additional services. Eric Detmer, Jaime Gibson, Jennifer Marinello and Michael Zocchi looked at how the museum might make the most of that space and surveyed visitors to determine the demographic mix and the types of administrators needed to implement changes.

A Warehousing Analysis

Atlas Industrial S.A. manufactures and distributes appliances throughout Costa Rica. After Electrolux purchased 20 percent of the company's stock, product volume increased and markets expanded, resulting in an overcrowded finished-product warehouse. Kate Burgess, Julie Kernis and Anthony Roccisano helped Atlas conduct a cost analysis that showed that expanding the current facility would be more effective than renting new space.

Reinventing the Garden

Lesley Chamberlain, Eric Las, Tim Miranda and Chris Tullman worked with the Lankester Botanical Gardens in San Jose. They analyzed and recommended software to track botanical information and create a map for the garden; developed a fund-raising program; redesigned the garden's Web page; restructured the inventory control process; and developed detailed greenhouse maps.

Environmental Marketing

Matthew Cole, Rodolfo King and Vrinda Nargund constructed a Web site for scientists interested in using the extensive rain forest system as a laboratory. Their mission was to advertise the Central Volcanic Cordillera Conservation Area (ACCVC) as a location for scientific studies. The students' plan included entrance brochures, signs, training programs for tour guides, and recommendations for foods to be sold at the site.

Telecommunications Analysis

ICETEL, the telecommunications division of the Costa Rican Institute of Electricity, is an autonomous government agency that holds a monopoly in the nation's electricity and telecommunications industries. To help it assess consumer needs, Malinda Danforth, Park Hays and Jocelyn Songer created a three-part system dynamics model to predict demand in Guanacaste and developed a detailed methodology ICE could use to expand the model to other regions. The entire assessment was done in Spanish.

A Focus on Waste Management

In return for some concessions, Baxter I.V. Systems Corp. donates its reusable and recyclable waste materials to the local municipality of Cartago. The company wanted to track its waste and reduce volume by 5 percent by the end of this year. Dina Carreiro, Michael Lavoie and Victoria Regan developed a database for Baxter to track and better manage cardboard and plastic packing waste.

Vernon-Gerstenfeld and her husband, WPI management Professor Arthur Gerstenfeld, served as project advisors. "Costa Rica, a thriving, modern industrialized nation, offers opportunities for WPI students to become immersed in a Central American culture where democracy, economic development and concern for the environment are a permanent part of the landscape," she says.

—BONNIE GELBWASSER

A High-Stakes Game of Cat and Mouse

Every day, millions of Americans tap into a sprawling global communications network, sending and receiving untold quantities of information through a largely insecure tapestry of copper wire and fiber-optic cable. As they transmit their orders and credit card numbers to online stores, dispatch confidential e-mail messages to friends or make long-distance calls with prepaid calling cards, they leave footprints —traces of themselves and their private lives— behind on the digital landscape.

The endless flow of information through the world's computer and telecommunications networks has become the subject of intense interest for researchers, businesses and entrepreneurs.

As you will see in the three stories that begin on page 4, the endless flow of information through the world's computer and telecommunications networks has become the subject of intense interest for researchers, businesses and entrepreneurs. Some of that interest revolves around the challenge of keeping track of those billions of bits and bytes. For Jay Gainsboro '75, that gargantuan task became the foundation of a successful business, one that catapulted him briefly into the national media spotlight.

Many others, including WPI professor Christof Paar and the alumni at GTE CyberTrust Solutions, are driven by a different challenge—finding ways to erase those virtual footprints, or at least hide them from information spies and thieves. The desire to keep information out of the hands of those who might illicitly profit from it has preoccupied governments, armies and businesses for centuries. In fact, historians of cryptography—the art and science of data scrambling—date the use of encryption back at least as far as 1900 BC.

With the rise of the Internet, the World Wide Web and the exploding domain of online commerce, the field of information security has taken on a new sense of urgency. The quest for newer, faster and more effective methods of encrypting information, and the equally compelling drive to break them, has become a high-stakes game of cat and mouse. It is a contest that marries the ancient mathematics of number theory with the latest high-tech tools of electrical and computer engineering.

While modern digital computers and global computer networks have opened up a new world of applications for cryptography, many of the challenges today's data scramblers face and many of the tools they use first made their appearance many years ago. In fact, the era of modern cryptography dawned 90 years ago with the brainstorm of Gilbert S. Vernam, a WPI graduate.

Vernam received his bachelor's degree in electrical engineering in 1914 and went to work for AT&T in New York. He joined a group of engineers who found themselves face to face with a conundrum that would sound quite familiar to cryptographers today: how to guarantee the security of private messages transmitted over a public communications network whose very design made it easy to intercept information. The network was not the Internet, of course, but the spider's web of telegraph wires that crisscrossed the nation.

The engineering group had been asked to study the security of the printing telegraph. They quickly discovered that even when multiple messages were speeding through a telegraph wire in both directions, a savvy hacker with an oscilloscope could monitor the frequency changes and transcribe the messages. After mulling the problem over, Vernam found an ingenious solution.

Printing telegraph machines typically used paper tapes for translating messages into electrical pulses and turning those pulses back into text. Vernam suggested using a second tape with a set of random pulses—a private key, in cryptographic terms—that would be added to the pulses of the text to create an encrypted message. An identical tape at the other end would enable the added pulses to be subtracted to reveal the message. Anyone intercepting the message would see only a meaningless jumble of pulses.

The idea of encrypting messages was nothing new. What Vernam accomplished was a method of coding and decoding messages automatically, in real time, which made cryptography, once a labor-intensive process that had to be done off-line, something that could be easily added to any communications system, from telephone calls, to radio transmissions, to e-mail messages flashed over the Internet.

Vernam's invention made him one of the "household names" of cryptography, and his accomplishments are included in many books on the field, including David Kahn's 1996 book *The Codebreakers.* Another seminal achievement in cryptography, the only unbreakable cryptosystem, called the one-time pad, is also often attributed to Vernam, because it arose from his invention of the encrypting telegraph machine.

Not long after he learned of Vernam's discovery, Major Joseph Mauborgne, head of the U.S. Army Signal Corps, discovered that if one employed a unique random key of the type developed by Vernam for each message and used each key only once, the result would be a system that even the most sophisticated code cracker could never break. Though impractical and rarely used (at least in commercial cryptography), such one-time systems are widely known in the field. (Interestingly, at press time, a firm known as Ultimate Privacy announced that it would market a cryptographic program for corporate networks that employs a one-time pad system.)

Vernam, who died in 1960, was president of the Wireless Association and a member of Tau Beta Pi, the engineering honor society, while at WPI. He spent 46 years in the communications field, earning 60 patents covering his work on cryptography, TWX systems, relay systems and switching centers. Nearly 40 years after his death, his work lives on in laboratories at WPI and around the world, where engineers, computer scientists and mathematicians continue the search for security that he began.

—MICHAEL DORSEY

"Who goes there?"

One of the thorniest problems facing Internet commerce is how to know who's really on the other end of the line. A group of alumni at GTE CyberTrust Solutions is solving the Net's identity problem with electronic passports.

BY ELIZABETH WALKER

Tom Cruise could have been stopped. As agent Ethan Hunt in the film *Mission Impossible*, Cruise trips up retinal scan, fingerprint and voiceprint security systems and ferrets out identification codes to gain entry to the CIA's "secure room" and download the agency's most sensitive data. But agent Hunt would have hit a virtual brick wall had he been trying to break in via the Internet and faced the data security and electronic identification systems designed, marketed and managed by Joseph Vignaly '82, Jeffrey Breed '85, Jeanne Gorman '87 and others of GTE CyberTrust Solutions.

In the real world of high-tech online data security, "you can't do a 'Tom Cruise,'" says Vignaly, director of marketing and business development for CyberTrust. "The security breaches through which Cruise and his coterie easily assumed and discarded identities in cyberspace could not have happened if our company's certification authority system had been in place."

One of Vignaly's favorite *New Yorker* cartoons illustrates pointedly the pitfalls of doing business over the Net, where people and businesses are known only through the electronic facades they present to other users. The cartoon shows a dog sitting at a computer. The caption reads, "No one knows you're a dog on the Internet." CyberTrust helps customers and vendors unveil the Net's "dogs" by providing a reliable means to verify the identity of another user.

This is more than a matter of satisfying one's curiosity. Being able to certify the identity of an individual, a business or a Web site is critical to the secure conduct of communication and commerce over networks. Banks want to know that users making withdrawals are entitled to the money. Retailers want to know that a customer is authorized to make purchases with the credit card number he's presenting. Stock brokers want to feel confident they know who they are trading with. And consumers want to know that the Web businesses they patronize are legitimate.

Vignaly says that it is also important to everyone doing business over the Net that their transactions have not been tampered with while in transit. "If someone issues a stock trade online, asking a broker to sell 100 shares, he wants to be assured that the broker gets the message he sent, and not one that's been changed to say, 'Sell 1,000 shares of stock.'"

To establish electronic identities, CyberTrust uses digital certificates that verify that all parties involved in a transaction are who they say they are. "Digital certificates are basically a means to securely identify yourself over the Internet. They are like a passport or a driver's license," Vignaly explains.

The certificates, which use the Secure Electronic Transaction (SET) protocol, can also be used to control access to data and Web sites, to ensure privacy for Internet transactions, to assure the secure transmission and integrity of sensitive information, like credit card numbers, and to provide proof that an electronic transaction has taken place. The key to the integrity of the certificates is that they

JONATHAN KANNAIR

Like high-tech security guards, the digital certificates developed by, from left, Joe Vignaly, Jeanne Gorman and Jorge Guajardo verify the identity of travelers on the information highway to make on-line transactions safer and more secure.

are "signed" by a trusted third party, a certification authority like CyberTrust, which binds its own digital identity to the certificate's public and private keys (for more on public-key cryptography, see "How Private? How Safe?," page 8).

Vignaly says digital certificates are safer and more reliable than traditional means of verifying the identity of computer users, including passwords and PIN numbers. "There's no way you can use PINs or passwords over and over again and keep them secure," he says. "Usually, the more PINs and passwords people have to remember, the easier they make them, increasing the risk of misuse and theft. With digital certificates, there's nothing to remember."

Vignaly cites the *Wall Street Journal's* on-line subscriber service as an ideal candidate for digital certificates. Currently, each subscriber gets a password to access the *Journal's* Web site. But when a password is given to somebody who has not paid to use the service, the newspaper loses revenue. "Digital certificates enable companies to limit use of their services and products to an individual rather than to a password," he says.

CyberTrust Solutions is a three-year-old commercial initiative for GTE, a telecommunications company known worldwide for developing government and defense communications systems and equipment. Its customers include the National Security Agency. CyberTrust evolved from work that GTE Government Systems was doing in high-security cryptography—specifically, developing key management systems for governments. The parent company quickly recognized that its electronic security products had wide-ranging commercial applications that could be tailored to business customers' specific security needs.

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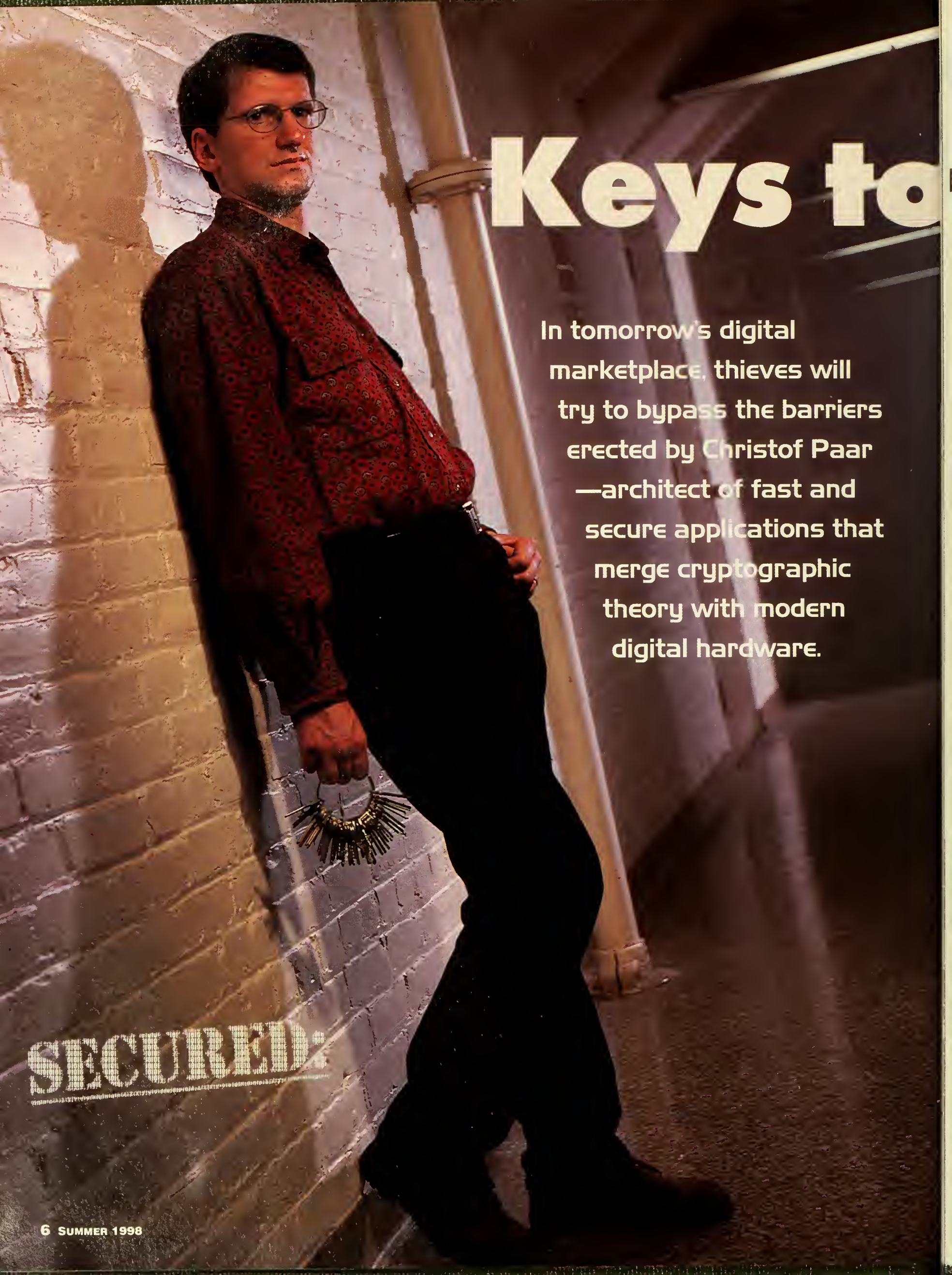


Keys to

In tomorrow's digital marketplace, thieves will try to bypass the barriers erected by Christof Paar —architect of fast and secure applications that merge cryptographic theory with modern digital hardware.

SECURED

the Future

BY MICHAEL W. DORSEY

The age of on-line commerce has arrived. Already, consumers can turn on their computers and buy everything from books to groceries to stocks to cars without leaving their homes or offices. All it takes is a modem, a Web browser and a credit card. But that's just the beginning, say technology forecasters, who predict that within the next five years anywhere from $300 billion to $1 trillion worth of business will be transacted over the Internet each year.

Perhaps the most remarkable fact about the explosion of Web-based business during just the past half decade is that the flow of orders and cash is taking place over an insecure conduit, one whose open structure—designed by academics for the free exchange of ideas and data—makes intercepting and altering sensitive information child's play. As more computer users tap into the Internet with wireless connections in the years ahead, snatching data may become even easier.

What has made possible the early success of Internet business—and what will prove absolutely vital to its future expansion—is a relatively new discipline that marries esoteric mathematics with computer science and electrical engineering. Called modern cryptography, the field is a digital descendent of cryptology, the centuries old practice of scrambling messages to keep state secrets and military communications from falling into the wrong hands. Once, cryptography was practiced almost exclusively by governments. But as businesses and researchers seek more effective and more efficient methods for encrypting information, data scrambling is becoming more and more the province of industry and academia.

"There is a gold rush for applications in cryptography today," says Christof Paar, assistant professor of electrical and computer engineering and founder of WPI's Cryptography and Information Security Research Laboratory (CRIS). "The Internet is taking off, with everyone thinking they can make some money in the on-line world. Financial transactions require security, so this growing desire to profit from the Net is the driving force behind an explosion of new security applications, including digital certificates, smart cards and digital cash."

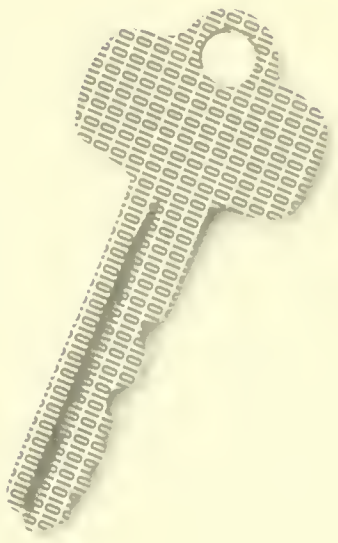
Paar is one of the rising stars in this brave new crypto-world. He came to WPI three years ago after earning his bachelor's, master's and doctoral degrees in Germany, the last at the Institute for Experimental Mathematics at the University of Essen. His early research, conducted in Germany, as an exchange student at the Michigan Technological University, and as a visiting researcher at the University of Massachusetts, Amherst, focused on error codes, mathematical functions that enable audio and video CDs to continue playing even after they've been scratched.

"Error codes were already fairly well-established, so I came to WPI looking for a newer, hotter area of applications," he says. "Since the early 1990s, cryptography has been a fast growing field, and it happens to rely on the same mathematical principles as error codes."

Those principles belong to a field known as number theory, one of the oldest areas of mathematics. With its roots extending back to the writings of Pythagorus, number theory deals with the properties of integers and their relationship to one another. Until recently, it was thought to have no real-world applications. Number theory entered the limelight in 1976 with the publication of a seminal paper by Whitfield Diffie and Martin Hellmann. Diffie and Hellman invented public-key encryption, which solved a central problem in cryptography that had threatened to limit its utility in the blossoming on-line world (see "How Private? How Safe?," page 8).

The development of public-key cryptography coincided with the rise of electronic commerce, wireless networks and high-quality multimedia services. What ties these emerging technologies together is the need to be able to send and receive large volumes of data across insecure networks in a safe manner. To meet this demand, a host of cryptographic software applications, with names like RSA, PGP (Pretty Good Privacy) and SSL (Secure Sockets Layer), have found their way into popular Web browsers and onto widely used commercial Internet sites.

For the most part, Paar says, the development of network security technology has been the exclusive province of computer scientists and mathematicians. In fact, Paar is one of relatively few researchers in the nation approaching cryptography from the perspective of an engineer. "One important aspect of modern cryptography," he says, "is implementing security protocols in hardware—chips, circuit boards, special-purpose



computers, and so on—which is what electrical and computer engineers do. Few other research groups have the interest—or the capability—to pursue cryptographic hardware in such a systematic manner."

In CRIS, several graduate students and a number of teams of undergraduates completing their Major Qualifying Projects are focusing their efforts on two broad areas: the development of hardware architectures for modern cryptographic schemes and research in the area of fast software algorithms. Paar's research on both fronts has won him more than a half million dollars in grants and contracts from such companies as GTE Government Systems, Lockheed Martin, Texas Instruments, Technical Communications Corporation, and Bosch, a German company. Much of the current work in CRIS revolves around making cryptographic systems faster and more efficient. In part, that means developing speedier algorithms.

"RSA is the industry leader in public-key cryptography, accounting for the majority of commercial applications, including the security feature in the popular Netscape browser," Paar says. "But because the keys used in RSA applications are so large, and require so much arithmetic to process, security systems are becoming relatively slow. So people have started to look at alternatives."

One popular alternative that is rapidly gaining in acceptance employs a set of one-way mathematical functions known as elliptic curves. The advantage of elliptic curves is that they appear to provide as much security as RSA and similar public-key algorithms, but with much smaller keys (150 to 250 bits for elliptic curves, vs. 1,024 to 2,048 bits for RSA). "Elliptic curves execute much faster than RSA, but the big question is whether they really are as secure." (See "How Private? How Safe?," this page.)

Paar's research group has been looking, not at the security of elliptic curves, but at how to make them execute as fast as possible. The team has derived a new algorithm related to elliptic curves and has earned a patent for one particular fast implementation method.

This summer, Paar and Daniel V. Bailey '98, a computer science graduate who is working toward a master's degree in Paar's lab, presented a paper at Crypto '98, the nation's largest and most competitive conference on cryptography. The paper was based on Bailey's Major Qualifying Project, co-advised by Paar and Stanley Selkow, professor of computer science, which won the Provost's MQP Award in computer science in April. [Another MQP advised by Paar won the Provost's Award in Electrical and Computer Engineering in 1996.] The paper by Bailey and Paar details a method for speeding up elliptic curve cryptosystems using a mathematical approach Paar and Bailey call Optimal Extension Fields.

One of the most effective ways to speed up cryptographic algorithms is to implement them

(Continued on page 10)

How

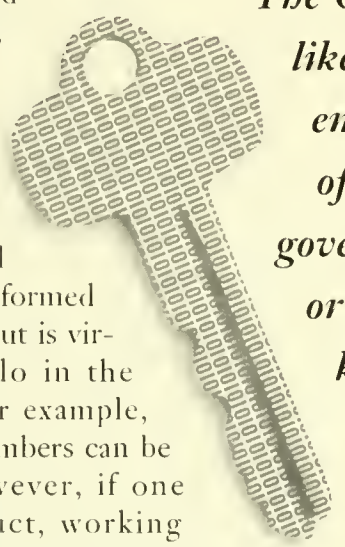
Over the centuries, cryptographers have devised many ways to encode messages to make them unreadable to all but their intended recipients. They range from simple substitution, where each letter of the alphabet is replaced by another letter or a combination of letters, to ciphers, mathematical treatments that transform and jumble the letters in a message in complex ways. But no matter what methods are used, all cryptography systems make use of keys that enable recipients to unlock and read encrypted text.

Traditionally, the only way to assure that encrypted messages remained secure was to keep the keys secret, which usually meant hand-delivering them to the intended recipients. For small organizations like banks with just a few branches, or for organizations with established methods of transporting sensitive information, such as the military or the diplomatic corps, that was not a problem. But when the senders and receivers of encrypted messages became millions of computer users all over the globe, keeping keys a secret became a seemingly impossible feat.

In 1976, Whitfield Diffie, a professor at Stanford University, and Martin Hellman, a graduate student, proposed a solution to this thorny problem. In a paper titled "New Directions in Cryptography" published in *IEEE Transactions on Information Theory*, they introduced the idea of public-key encryption, which uses two keys: a private key that only the user knows, and a public key that is distributed freely. To send a secure message to another user, one encrypts it using the recipient's public key. The message can then only be decrypted by the recipient using his private key. An additional advantage of public-key encryption is that it can be used to create unforgeable digital signatures. A user creates a digital signature using her private key; it can only be unlocked with her public key. Since only someone who knows the private key could have created the signature, it verifies the sender's identity.

The first popular application of public-key cryptography was a product called RSA (named for the first letters of the last names of its inventors, MIT mathematicians Ron

Private? How Safe?



The Clinton Administration would like to require that all strong encryption schemes have a sort of back door that would let the government unscramble messages or that users place their private keys in an escrow account with a third party.

Rivest, Adi Shamir and Leonard Adleman). RSA, developed in 1977, makes use of trap-door, one-way mathematical functions.

A one-way function is a mathematical operation that can be performed easily in one direction, but is virtually impossible to do in the opposite direction. For example, two very large prime numbers can be easily multiplied; however, if one knows only the product, working backward to determine the original primes is virtually impossible if the number is large enough. A trap-door is another number or function that, if known, turns a one-way mathematical function into a two-way function—one that can be completed easily in both directions. In simple terms, the public key in RSA is related to the product of two prime numbers, while the private key is related to the prime numbers themselves and the trapdoor function.

For the nascent on-line business community, the availability of public-key cryptography was a Godsend. It helped overcome one of the greatest fears of potential consumers by making it possible for the first time to send e-mail, credit card numbers and personal information securely over the world's most insecure network, the Internet. But, notes Christof Paar, assistant professor of electrical and computer engineering, it can sometimes be a bit difficult to say just what "secure" means when it comes to encryption.

"Cryptography is a weird field," he explains. "In practice, you can never really prove that an algorithm is secure. You publish it and you hope a lot of people try to break it—and don't succeed. The recent history of modern cryptography is rich in examples of promising algorithms that were quickly broken."

The future of on-line commerce depends, in no small measure, on whether enough potential customers feel confident enough in the unbreakability of modern cryptographic algorithms to entrust their credit card numbers and personal information to the unprotected by-ways of the Internet. But as Paar notes, using any cryptographic algorithm is an act of faith.

Recent developments in the on-line world have demonstrated that even tried and true encryption systems can be vulnerable to attacks by a persistent hacker or by a researcher with the right resources and enough time. In June, a scientist at Bell Laboratories discovered a hole in a system used widely on the World Wide Web to encrypt passwords, credit card numbers and other sensitive information. Called the Secure Sockets Layer or SSL, it's the software that locks the little padlock in Netscape and Internet Explorer, telling users their communications are secure.

The flaw might have enabled a hacker to determine how to unscramble secret information by analyzing the patterns in error messages returned after failed attempts to read encrypted data. The researcher found that he could unlock the code after anywhere from one million and four million unsuccessful tries. Although it's unlikely that anyone has been unable to take advantage of the bug, a group of major software companies quickly developed a fix that plugged the hole.

Less than a month later, a group of cryptographers found a way to crack the Data Encryption Standard (DES), perhaps the most widely used data scrambling algorithm in the world. Using brute computing strength in the form of a custom-built, $250,000 cracking computer, they worked through 90 billion possible keys every second for 56 hours straight until they found one that worked. In all, they tried about a quarter of all possible keys.

The widely publicized feat heated up the debate over the U.S. government's policy on the export of encryption systems. Currently, the federal government, considering cryptography a military technology, restricts the export of encryption systems to foreign governments and companies. Although the rules are complicated, in general exported software is limited to 40-bit encryption (vs. the 56-bit to 128-bit systems commonly used in the United States), unless the systems give the government access to the keys needed to decipher messages. The relative ease with which a 56-bit DES key could be deciphered has made many observers ask whether the government is justified in relegating foreign computer users to much weaker 40-bit algorithms.

The encryption debate is not limited to software exports. The government, particularly the FBI, has always been wary of making it too easy for criminals to scramble their secret communications with unbreakable ciphers. Accordingly, the Clinton Administration would like to require that all strong encryption schemes have a sort of back door that would let the government unscramble messages or that users place their private keys in an escrow account with a third party, where the government could get them as part of a criminal investigation. The software industry and organizations like the Electronic Freedom Foundation believe that the government has no business being able to snoop on private citizens and that solutions like key escrow could prove highly expensive for the government and the private sector.

As Net commerce continues to grow, and as the value of the goods and services bought and sold over the global information network skyrockets, the demand for stronger and more confidence-inducing cryptography will likely rise in step, as will efforts to thwart it and control it.

—MWD

KEYS TO THE FUTURE

(Continued from page 8)

with dedicated hardware. Building a system into a computer chip or plug-in board not only makes it run faster, but makes it more secure, Paar says. "If your crypto system is running as software on your PC, there's a potential weakness because an attacker could get access to the algorithms or your keys. If everything is running in a chip, the physical access to that information is greatly restricted. The National Security Administration has known this for a long time, and now the commercial sector is slowly realizing that to get the greatest security, you need to start out with hardware."

One innovative approach to developing hardware for cryptography recently won Paar a prestigious faculty career development grant, called a CAREER Award, from the National Science Foundation. The four-year, $210,000 award will support the development of cryptographic systems using reconfigurable hardware. "This is the first NSF grant for crypto-hardware," Paar says.

"My proposal to the NSF combined two of the hottest areas in electrical engineering, cryptography and reconfigurable hardware. Usually, the disadvantage of implementing algorithms in hardware is that you give up the low development costs and flexibility of software. Once hardware is built you're stuck with it, but reconfigurable hardware is reprogrammable, so it combines the flexibility of software with the security of dedicated hardware. It represents a real paradigm shift in digital engineering."

Paar will be using a type of reconfigurable hardware known as field programmable gate arrays (FPGAs), logic chips that can be reprogrammed on the fly. "One of the new trends in cryptography is building systems that are algorithm independent," Paar says. "That means that the user and the server negotiate about which algorithm will be used in a particular transaction. Achieving this flexibility with software is not too difficult, but how can you do that with hardware? We are probably the first research group to think about doing this systematically with FPGAs."

Building hardware that can reconfigure itself within microseconds to run vastly different algorithms that employ keys of widely varying lengths will be no easy task, Paar says. Just designing a plug-in PC board that can handle the complicated arithmetic involved in processing a single cryptographic algorithm will be a challenge. "Your PC is designed to do math with 32-bit numbers," he says. "With RSA, you must perform computations with numbers that are 30 to 40 times that length. We have to look carefully at the kinds of gate structures that will allow that kind of arithmetic."

While the development of algorithm-independent FPGAs is just beginning, Paar and his students have already used the devices to speed up the implementation of the most widely used private-key algorithm, the Data Encryption Standard or DES. Developed by the federal government in the 1970s to be the standard for strong encryption, DES is used in applications where keys can be exchanged securely and is also the backbone of some public-key applications.

"Using FPGAs, we did an incredibly fast implementation of DES," Paar says. "In software, you are limited to data throughput speeds of about 10 megabits per second. With dedicated hardware, you can achieve speeds of up to 1,600 megabits. Our implementation was clocked at 400 megabits per second."

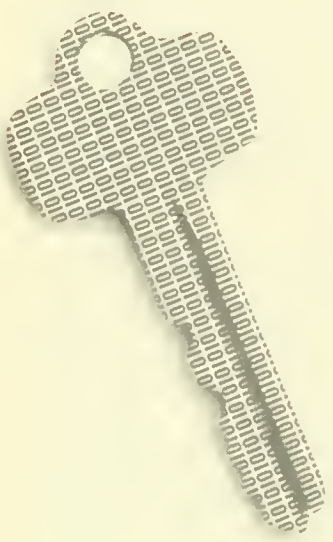
Because of the importance of information security to the future of on-line commerce, Paar's cryptography group at WPI has been in demand not just as researchers, but as educators. Paar teaches two graduate courses on cryptography and data security that have been offered on campus and, for three years running, on-site at GTE Corporation in Waltham, Mass. "Just a few years ago, when we first offered the initial course, we were one of the pioneers," he says. "Now, a number of universities offer one course, but only a few offer a follow-up course, as we do."

Paar also teaches a short course on applied cryptography and data security through WPI's Office of Continuing Education. It has proved a popular offering at WPI's Waltham Campus and has also been delivered at the NASA Lewis Research Center in Cleveland, Ohio, and at Philips Research Laboratories in Briarcliff Manor, N.Y. For the past two years, CRIS has offered the WPI Cryptography and Data Security Seminar Series. This year's series included speakers from WPI, the University of Massachusetts, MIT, GTE CyberTrust and RSA Labs.

Like Paar's courses and seminars, his students are in great demand. "Job opportunities in this field are completely crazy," he says. "There are many companies that are in or are just getting into Internet businesses, and they are desperately looking for people who are fluent in cryptography. There are very few schools that are offering this program, and even fewer schools doing it from an engineering perspective."

The German high-technology firm Secunet, a new subsidiary of one of the country's oldest technical holding companies, was so keen on hiring a student trained in Paar's lab that it held a contest, with the first prize being a one-year graduate fellowship in WPI's Electrical and Computer Engineering Department. The first recipient is Harald Weidner, a Ph.D. candidate at the University of Zurich.

"Our approach to cryptography is clearly what companies are looking for," Paar says. "But it is also, in a real sense, in tune with what WPI is all about. The University's philosophy is about combining theory and practice. That's what we do here. We take the theory of a highly arcane mathematical field, and implement it in a practical, usable manner. It's an approach that has proved highly successful for us, and for our students." ■



Who Goes There?

(Continued from page 5)

"Bankers, retailers, credit card companies and other business clients seek the confidence, protection and privacy of traditional, face-to-face transactions as they conduct business by highly impersonal electronic means," Vignaly says.

"Our philosophy is that while the technology is new, the relationships between vendor and client have remained the same. What you need to know is that the people you're talking to are who you think they are. The traditional standards of trust that begin with eye contact and a handshake are not possible when you move business and legal transactions onto the Internet."

Not long after Vignaly went to work for GTE he moved from doing project-focused engineering to managing programs, then on to product management in what he calls a step-by-step migration. Along the way, he earned an M.B.A. at Babson College. Today he is fully immersed in the product side of the business, but finds that his solid understanding of the technology behind each project serves him well. At times, it causes his non-technical colleagues to confer upon him a little mystique he believes is unwarranted.

"I do absolutely nothing related to my degree in mechanical engineering now," he says. "The advantage I have is that WPI taught me to break down a problem, analyze it, solve it, get it running and move on to the next project. While others might throw up their hands and say, 'It's math; I can't do it,' my technical background enables me to answer the broad questions and give potential customers an explanation of what's going on with the products we promote."

Jeff Breed's career has also evolved considerably since he joined GTE in 1985. Back then, the products he works with today—in fact, the whole electronic security industry itself—did not exist. He started out doing hardware design and eventually moved into customer support. In his current post as program manager, he oversees the development of complicated software solutions to electronic security problems that customers bring to CyberTrust. "We define the appropriate platform on which to run the certification authority software package we offer," he says. "Then we help integrate the customer's existing technology with the new platform, build the business around it, and train the customer to use it."

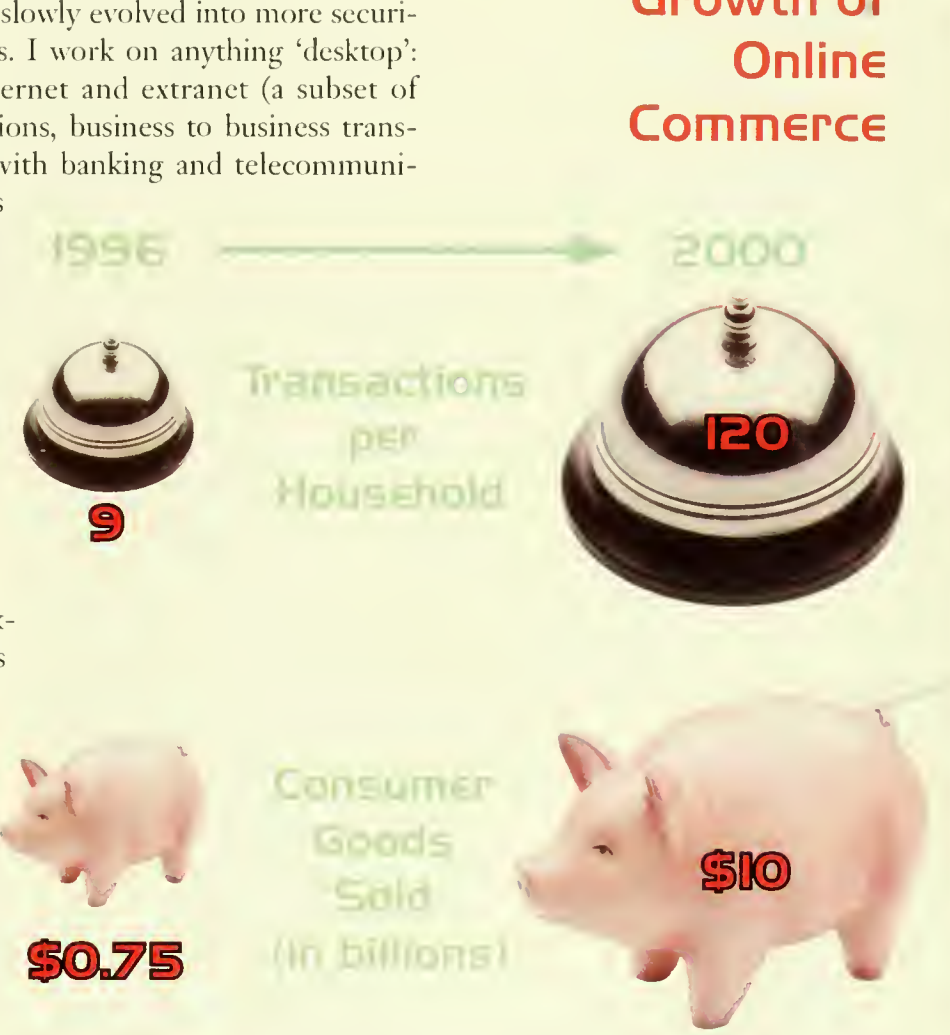
Breed says it is no surprise that GTE likes to hire WPI graduates. In addition to the obvious geographic considerations, Breed says WPI alumni are a natural fit at CyberTrust because of the strong technical and project-oriented education they bring to the company. "The focus on project work at WPI is important because that's the way industry works," he says. "The technical projects I worked on at WPI helped me think in broader terms and recognize how my work affects the work of others. I also think WPI attracts well-rounded people who have a broad array of interests and good communications skills."

GTE's CyberTrust division also employs David J. Altieri '76, Timothy J. Dray '85, Mohamed Dembele '95, Jorge Guajardo '95, Anu Karna '98, Richard L. Laferriere '89, Sergey Perepelitsa '96 M.S., Eugene R. Valois '89 and Benjamin Wu '94 M.S., and has been adding one or two new WPI grads a year. GTE and CyberTrust also work on other projects with WPI faculty and graduate students, including electrical and computer engineering professor Cristof Paar (see page 6).

Like Vignaly and Breed, Jeanne Gorman is working in an area she didn't foresee when she joined the company. "I went right to GTE after graduation thinking I would design hardware," says the electrical engineering major, who now works on access-control products. "I've had five different jobs at GTE as the communications projects I worked on slowly evolved into more security-related projects. I work on anything 'desktop': Web-servers, Internet and extranet (a subset of Internet) applications, business to business transactions—mostly with banking and telecommunications customers who are looking for technical solutions."

All three graduates see the financial and telecommunications industries as the most interesting and forward-thinking global markets when it comes to electronic security. "American Express and MasterCard are our cornerstone customers," says Vignaly. "We provide certification authority services to them from our Needham facility. We also have a number of international telecommunications customers, including Deutsche Telecom, Telecom Italia, and SwissCom, and a joint venture underway with Japan's NTT and the Nomura Research Institute."

Looking ahead, Vignaly sees the technology evolving and expanding as the company works to outpace high customer demand worldwide with solutions that provide even greater levels of security and reliability. ■



SECURED:

BY ELIZABETH WALKER

Name a person, place and thing that link deposed hotel queen Leona Helmsley, drug-dealing despot Manuel Noriega and convicted killer James Earl Ray. Try Jay Gainsboro '75, prison and the telephone.

When Helmsley, Noriega and Ray phoned home—or anywhere else—during their incarcerations, they shared a vital connection to this entrepreneurial WPI alum and they all paid for it—prepaid in fact. This infamous trio, whose collective rap sheet includes tax evasion, drug dealing and murder, has been counted among the "captive" client base of prisoners worldwide who use The Enforcer, an inmate telephone control and billing system developed by Opus Telecom Inc., Gainsboro's privately held company. Not long ago, Framingham-based Opus put its technology and Gainsboro's nerves to the test by focusing all its energy on a new customer. It was that attention to detail for which the company is widely known that helped convict Oklahoma City bomber Timothy McVeigh.

Opus Telecom, founded in 1979, specializes in applications of what is known as computer telephony integration or CTI. Opus makes CTI products primarily for two markets: prepaid telecommunications systems (such as prepaid phone cards) for the "teledebit" market and inmate telephone systems for the corrections market. Gainsboro, president and sole owner, says the company's two current strengths are prison calling and control systems and prepaid wireless communications, though it also has the burgeoning international telecommunications market in its scope.

Gainsboro, who holds several telecommunications patents, estimates Opus' combined sales at about $30 million. He says the company's 50 employees process 30 million calls a year at more than 80 sites in the United States and Europe. The company's major partners include AT&T, MCI, British Telecom and Lucent.

(Continued on page 14)

Two decades ago, Jay Gainsboro founded a company that is today one of the most important players in the prepaid phone card business and the inmate phone systems market. Little did he know that one day those businesses would converge in an investigation of one of the most heinous crimes of the century.

Life's Opus

JONATHAN KANNAIR

His Life's Opus

(Continued from page 12)

Among the many other functions they perform, Opus' busy computers track and store information on prepaid phone card use nationwide. It was a 17-month trail back in 1995 of a system to store debit card calls that helped convict Timothy McVeigh, whose bomb killed 168 people—including many children—and injured 500 others as it destroyed the Alfred P. Murrah Federal Building on April 19, 1995.

Using and recharging a phone debit card issued in the name of Darryl Bridges, McVeigh made nearly 700 calls, including some to former Army buddy Terry Nichols, to military surplus stores, to munitions and chemical companies, and to a Ryder truck rental outlet. Gainsboro and his team used their system to sift through eight billion bytes of stored data to identify the origin and destination of each call. The hundreds of non-reimbursed hours they invested helped federal prosecutors prove that "Darryl Bridges" was really Timothy McVeigh. "What I learned from this experience," says Gainsboro, "is that the government will find you if they put the resources in place to do it."

Opus' involvement in the McVeigh case began two days after the bombing, when Gainsboro got a call from an Opus client, West Coast Telecom (WCT). The caller, John Kane, was working with the FBI and the Secret Service to retrieve phone records concerning a suspect. Gainsboro and his team were asked to determine who made a 57-second call from the Dreamland Motel in Junction City, Kan., between 9 a.m. and 11 a.m. on April 17, 1995. The call, to an 800 number, went into WCT's switch, then into Opus' calling card platform. It was one call among 7.8 million calls tracked by Opus nationwide during that two-hour period. After identifying the call, the Opus system determined that the PIN and account number were for a phone card purchased from *Spotlight*, a magazine published by the Liberty Lobby in Washington, D.C. The Liberty Lobby provided the cardholder's name—Darryl Bridges. The FBI found a phone card in that name in the home of Terry Nichols and obtained other evidence linking the alias to McVeigh and Nichols.

The information was what federal prosecutors needed to start building their cases against the two suspects. After pinpointing that call, Opus was able to trace hundreds of other calls made with the card to people and businesses that figured in the preparations for the bombing. Gainsboro was slated to testify at McVeigh's trial in Denver, but was given an 11th-hour reprieve by a change in witnesses. "I was in the 'on-deck' room and was anxious," Gainsboro says. "I knew that the defense would try to undermine my credibility. I felt a tremendous responsibility to do a good job. I had met the families of the people who died. I got very close to the horrendous loss of life."

AP WIDE WORLD PHOTOS

Data recorded by Opus Telecom enabled federal investigators to link calls made with a prepaid phone card purchased in the name of Darryl Bridges to Timothy McVeigh. The evidence played a key role in McVeigh's conviction in the Oklahoma City bombing. Today, Opus tracks every call McVeigh makes from federal prison.

Supporting the government's efforts to convict McVeigh cost Opus about $100,000, but Gainsboro does not regret the time and resources he and his team invested. He cites those who claim that the phone records constituted 80 percent of the case against McVeigh. The records provided a kind of timeline—one that allowed the prosecutors and jury to watch, in retrospect, McVeigh's movements in the months, days and minutes leading up to the bombing.

Involvement in the high-profile Oklahoma City bombing was a sharp detour for Gainsboro, who never sought the limelight, just success. Growing up, he was surrounded by entrepreneurs. His father and uncles all owned their own businesses. After deciding at 14 that someday he

would start a high-tech company, Gainsboro turned to a successful family friend for guidance. The friend's formula included a degree from a good technological university. That advice brought Gainsboro to WPI.

"My education at WPI was excellent," he says. "I majored in management and took some basic engineering courses. When I look back at the value of my years at WPI, I think of one professor in particular, Joe Mancuso. He was quite entrepreneurial and took me under his wing. He had a strong influence on helping me understand business issues. It was at WPI that I met my future business partners, Russ Vickery, Jeff Birkner and Dave Erickson. They helped me get started."

Prior to founding Opus in 1979, Gainsboro helped his father start a new consumer products business in Chicago. While there, he became aware of new long-distance carriers, such as MCI and Sprint, that billed themselves as alternatives to AT&T. He estimated that using Sprint could save his father's new company 30 percent on long distance charges. Though touch-tone service was not available through the local phone company's outdated central office, he still managed to save $1.50 on his first call. Using a screw-in keypad that attached to his rotary-dial telephone, he was able to punch in the 23-digit access code Sprint and MCI users had to enter before dialing every number. Gainsboro immediately saw a tremendous money-saving opportunity for millions of businesses; his father saw an inconvenience.

"My father wouldn't use the keypad," Gainsboro says. "He had no patience with the 23-digit access code. His refusal was the impetus that drove me to find a solution to the problem. I went out and bought an auto-dialer, so all he had to do was dial five digits plus an authorization code, but my dad was still frustrated by all the numbers and wouldn't use it."

His father's second refusal spurred Gainsboro to turn to Vickery, Birkner and Erickson, who designed and developed a "store and forward" dialer. The new dialer made gaining access to alternative long-distance carriers virtually transparent to the caller. The business user would dial calls in the usual fashion, and the unit would analyze the digits, check the telephone network, and forward the calls to the appropriate carrier. That was the birth of Opus Telecom. Not surprisingly, Sprint was excited about the dialers, the first of which were sold to hotels and motels.

Sales of the new dialers reached $3 million by 1983, the year AT&T settled its antitrust case and U.S. District Court Judge Harold Greene decreed that consumers should have equal access to all long-distance carriers. The ruling marked the end of the dialer business. But Gainsboro, fascinated since childhood with the possibilities and potential of the telephone, went on to invent several other telecommunications products.

"We got into the real-time rating of phone calls, building call accounting systems that rated and tracked calls," Gainsboro says. "We started selling these to law firms, country clubs and the like. Until 1987 all the features we offered were contained in a small box. The Army forced us out of our box."

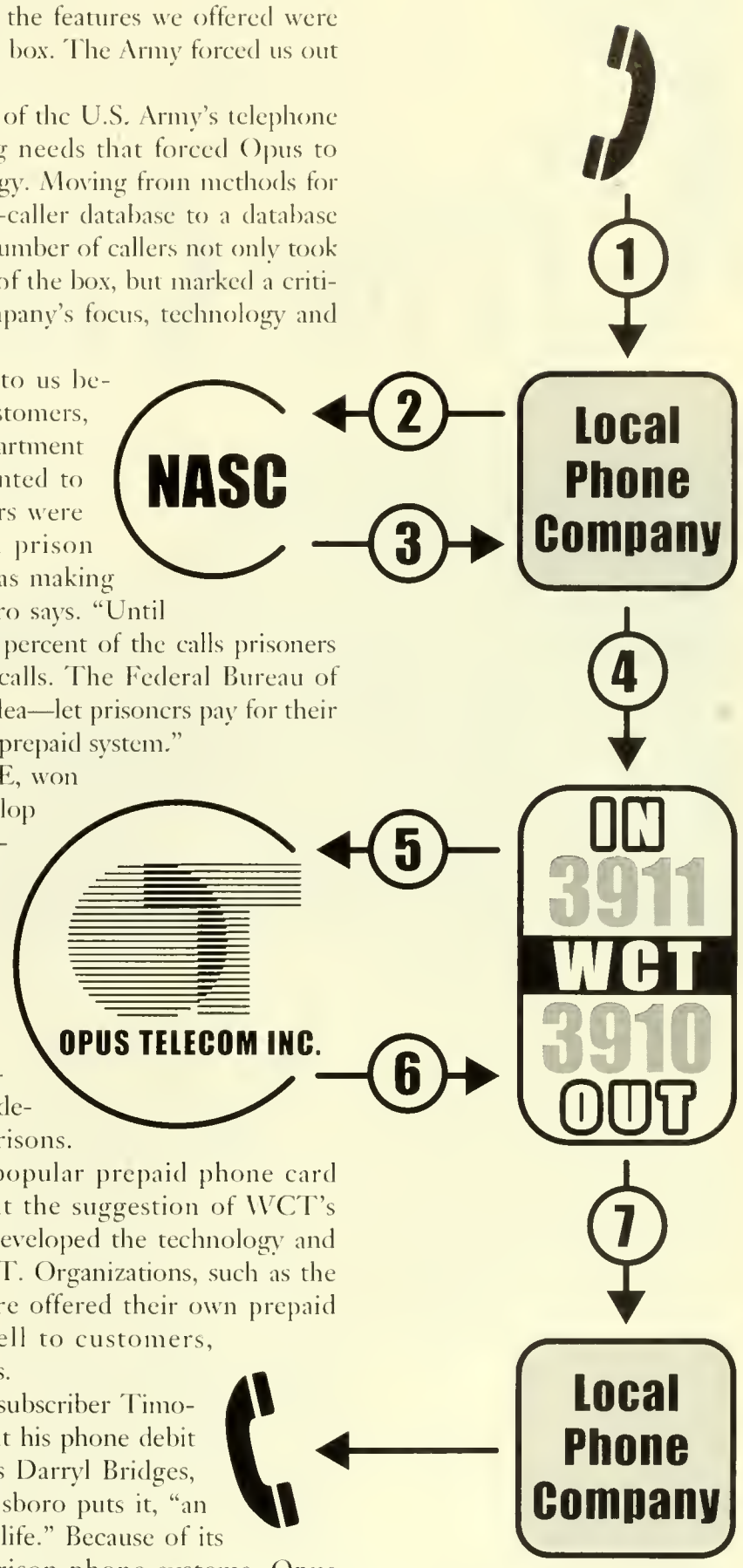
It was the scale of the U.S. Army's telephone tracking and rating needs that forced Opus to rethink its technology. Moving from methods for controlling a 3,000-caller database to a database with an unlimited number of callers not only took the technology out of the box, but marked a critical shift in the company's focus, technology and market.

"AT&T came to us because one of its customers, the New York Department of Corrections, wanted to know what numbers were being called from prison phones and who was making the calls," Gainsboro says. "Until that time, 80 to 90 percent of the calls prisoners made were collect calls. The Federal Bureau of Prisons had a new idea—let prisoners pay for their own calls through a prepaid system."

Opus, with GTE, won the contract to develop the new prepaid calling system, which quickly accounted for 80 percent of the market for prepaid and collect calling systems. In fact, prepaid calling technology was developed first for prisons. The idea for the popular prepaid phone card emerged in 1992 at the suggestion of WCT's John Kane. Opus developed the technology and sold it back to WCT. Organizations, such as the Liberty Lobby, were offered their own prepaid calling cards to sell to customers, clients or subscribers.

After *Spotlight* subscriber Timothy McVeigh bought his phone debit card under the alias Darryl Bridges, he became, as Gainsboro puts it, "an Opus customer for life." Because of its experience with prison phone systems, Opus maintains detailed records on all calls made with the cards it tracks. Had McVeigh bought his card in a retail store, it would have been more difficult to identify the card's owner, Gainsboro says. With McVeigh now behind bars, Gainsboro says he can expect the same high standard in customer service and attention to detail that helped land him there. Today, any calls McVeigh makes are tracked and stored in the Opus network database.

—Walker is a freelance writer whose last article for the Journal *was a profile of the late David Todd in the Spring 1998 issue.*



This flow chart shows the path taken by a 57-second call made by Timothy McVeigh with his prepaid phone card on April 17, 1995. After being routed through the 800 Number Administration and Service Center (NASC) and West Coast Telecom (WCT), the call passed through the computers at Opus Telecom, where detailed information about it was recorded.

NASA's administrator peers ahead to a future filled with exciting advances in space exploration, air transportation, Earth sciences and computing. But he says it will take revolutionary changes in engineering and engineering education to realize this vision.

One Giant Leap

NASA PHOTO

BY DANIEL GOLDIN

NASA is not just about opening air and space frontiers; we're also about building the tools we need to open those frontiers. While we've had some great successes, there's much more to do. We want to cut our system costs by about an order of magnitude. We want to cut our cycle time of development by a factor of 3 to 5, so we can build and launch a spacecraft within a year to a year and a half. We want to improve reliability by up to a factor of 10,000. To achieve these goals, we need bold, revolutionary leaps—not just at NASA, but in engineering and engineering education.

NASA has a bold strategic vision for the next 25 years. We want to develop technologies that cut travel time across the Pacific in half and cut costs and improve safety so space travel is not limited to our astronauts. We want to be able to make annual to multi-decade predictions of climate, environment and resource management to promote sustainable development on this planet. Within 10 to 15 years, we want to be able to detect Earth-sized planets around stars up to 100 light years away and see if those planets support life. Within 25 years, we want to be able to see geological and biological processes on those distant bodies. And we want to use the International Space Station as a platform so an astronaut can leave Earth orbit and maybe one day visit Mars or work on a research station on a near-Earth asteroid.

To make our vision a reality, we will need more intelligent systems, more flexible modular vehicles, breakthroughs in miniaturization, better, lighter materials, and advanced operating capability. For example, to send a probe to a distant star, where it will be too far away to receive operational commands from mission control, we'll need a spacecraft that can think for itself and learn and adapt as it goes. It will have to be self-diagnostic and self-repairing; in many ways, it will have to be like the human body. It will have sensors and actuators, it will react to stimuli, and it will adjust to changing environments.

Traditional numerical approaches will not work in such a spacecraft. Instead, we'll need soft computing that more closely resembles human intelligence—we need a vehicle IQ. We will develop modules from the chip level through the system level. With a modular design, we can assemble similar modules into different spacecraft to achieve different missions. This building block approach will also find its way into vehicles operating closer to Earth. For example, modular design will enable us to modify wing configuration to change the role of an aircraft.

To go beyond the solar system, we'll also need smaller and cheaper spacecraft. We've already made significant strides in that area. Viking, which landed on Mars in 1976, cost over $3 billion (in today's dollars), was about the size of a small car, and took about a decade to devel-

op. By contrast, Mars Pathfinder cost less than $300 million, was much smaller and took less than three years to develop.

In the future, the costs and the sizes of spacecraft systems will continue to shrink as their capabilities grow. In the near term, we plan to build spacecraft about the size of a television set. Ultimately, we'll develop nanospacecraft that will weigh less than a kilogram, fit in the palm of your hand and have their entire avionics on a single chip. These spacecraft, which will operate in some of the harshest environments known, will also benefit from advances in materials and design tools.

It's not just the spacecraft that must get smarter and smaller. We must also develop intelligent, streamlined control systems and continue to reduce the work force needed for space missions. For every person you see in the space shuttle mission control, there are many others behind the scenes. Launching the shuttle takes thousands of people and a few hundreds of millions of dollars. NASA's new X-33 experimental vehicle, which will fly next summer, will require no more than 50 people for operations. The Viking program required about 1,000 people in mission control; Pathfinder took about 50. Future missions will require 12 or fewer.

How do we get from here to there? How do we take the engineering design culture from where it is today to where it must be for the missions of tomorrow? For a long time, engineering was a pencil-to-paper culture. In the 1960s, we moved from slide rules to electronic drafting boards and wire-frame computer modeling. By the mid-1970s, we were using solid models to represent geometry and three-dimensional surface contours. Despite these advances, too much time was still wasted by the incompatibility of the analytical models used in such disciplines as aerodynamics, thermodynamics, structures and controls. The design process was sequential, with separate discipline groups. System design was optimized at the discipline level, not the system level. Data and design information had to be moved from one group to another—a task accomplished by people carrying large piles of paper.

About 20 years ago, we merged design with manufacturing. CAD/CAM, which significantly reduced design cycle, process time and engineering change orders, led to concurrent engineering—linking diverse disciplines through the use of digital data sets. The best example of concurrent engineering is the development of the Boeing 777. At the peak of design work, 238 design teams comprising 6,000 engineers, using data from 4,000 worldwide computer terminals, manipulated three trillion bytes of information representing 20,000 design releases.

But we still have a disconnect from discipline to discipline. We still have many distributed, unconnected databases across engineering fields and manufacturing. And because we don't have the capacity for real-time simulation, we can't get a real-time visualization and integration of all these tools. NASA is working to break this logjam. In our Product Design Center at the Jet Propulsion Laboratory, we are bringing disciplines together, which has enabled us to reduce analysis of preliminary mission design concepts from half a year to two weeks.

Because of the sequential nature and limitations of our tools, there is still far too much uncertainty throughout the life cycle of a product, there are too many people involved, and we have just begun to address the geographically distributed nature of what we do. We need to capture design knowledge earlier in the design process and learn to deal with the unprecedented quantity of data that confronts us and convert it into usable knowledge.

Because of current shortcomings, we commit about 90 percent of the cost of a new product when we only have about 10 percent of the knowledge about it. And the more we incur costs in any design process, the more our flexibility to make changes, without the risk of cost and schedule overruns, diminishes. As a result, we don't get an optimized design, products cost too much, and they're not as effective as they should

NASA PHOTO

DENNIS VANDAL

NASA's Dan Goldin was the featured speaker when the Industry/University/Government Roundtable on Enhancing Engineering Education (IUGREEE) held a major meeting on the WPI campus in May. It was the first time that the organization, whose membership includes WPI President Edward Parrish, had met on a university campus.

"Because of current shortcomings, we commit about 90 percent of the cost of a new product when we only have about 10 percent of the knowledge about it."

be. We must eliminate the discrete steps of conceptual design, preliminary design and final design, as well as manufacturing training, maintenance and operations.

How do we close the gap between design knowledge and cost commitments? At NASA we're using something called Intelligent Synthesis Environment (ISE). We're not just updating tools, we're fundamentally changing the culture of engineering. The major components of ISE are human-centered computing, infrastructure for distributed collaboration, rapid synthesis and simulation tools, life-cycle integration and validation, and the cultural and educational change we need to inject into the creative process.

Human-centered computing deals with the dynamics and interfaces between the human being and the computer. Our current way of interfacing with the computer is for WIMPS (Windows, Icons, Menus, Pointing Systems). It's not the way we deal with our real environment. We interact with the world, process information and make decisions based on all of our senses. In addition, there simply isn't enough coupling of humans and computers. We need to exploit research on human biology and the brain's cognitive processes. Perhaps someday we'll talk to our computers using alpha waves or the electrical activity in our muscles.

"We must understand, appreciate, integrate and exploit biological processes and their incredible potential. Our goals at NASA depend on that, as does the future of engineering. This is something our education system must reflect."

We must also learn to discover and integrate various sources of data, using active intelligent agents to "mine" data and present it to the user in a variety of formats, including text, numbers and multimedia images. This will help us move from data, to information, to knowledge, to intelligence.

Next, we need to build the infrastructure for distributed collaboration so we can take full advantage of diverse teams around the world. We need at least a hundred- to a thousand-fold increase in computer capability to achieve the ISE vision. We need to move into nonsilicon or nonelectric computers—perhaps to optical and biological computing.

That's why we also need to increase our networking capability. The amount of information flowing through the pipeline must increase from under a gigabit per second, where it is today, to at least one hundred to one thousand gigabits per second. Tomorrow's networks must have intelligent switches and routers, or intelligent interfaces. The increased networking ability will enable us to link computers, mass storage facilities—and people—seamlessly.

Though separated geographically, scientists and engineers will be able to work in collaborative teams in the engineering design process. They will be able to work together, using the full range of human senses, even if some of them happen to be on Mars. Each team member will be able to participate and communicate from his or her own creative perspective. They will be free from the keyboard and the terminal, which are literally locking up our creativity.

The third part of ISE is rapid synthesis and simulation tools. Today, because of limitations in our models, we oversimplify the real world. We rely on separate complementary test programs to establish worst-case operating and failure conditions to guide our analyses. To account for uncertainty and to quantify risk, we must move from traditional deterministic methods to nondeterministic methods, like probabilistic approaches, neural networks, genetic algorithms and symbolic computing.

We've already achieved a high level of sophistication in numerical simulations across many disciplines, but we need to do more. Today's technology limits us to about one billion nodal connections and one billion nodal interactions per second. We need to aim for the capability of the brain, which is more than one million times more powerful. Only rapid analysis and optimization capacity near this level will close the design knowledge-cost commitment gap and enable us to go from mission requirements, to multidisciplinary analysis and design, to simulation of manufacturing and virtual prototyping, to operations and repair, to product disposal. The virtual design process will also give us, with unprecedented detail, cost impacts and risk-level assessment.

To ensure that we have analytical models to verify real-world behavior and failure mechanisms, we need to integrate analytical models development in real time with experimental testing. This approach will dramatically shorten the cycle time of product development by enabling a seamless flow from initial concept through final design and manufacturing.

To date, industry has concentrated on simulation of manufacturing, planning and processes. We have simulators of individual machines and we have real-time assessment of inventory flow control. But we need to be able to simulate an entire factory before we erect it; an entire plane before we build it; an entire mission to Mars before we launch it. Then we can begin to simulate operations, including repairs and maintenance.

That brings us to the next component of ISE: integration and validation. At this point, there are many unknowns. We don't know what fidelity we need. We don't know what scale is required. We don't know how collaborative virtual teams will work. These are fundamental issues. To address them and demonstrate and validate the future collaborative design environment, NASA plans to establish national, virtual

distributed testbeds—geographically distributed computing environments that integrate hardware-in-the-loop, real-time information operating systems, and all associated engineering design tools.

At NASA, we want to focus these testbeds in critical areas such as reusable launch vehicles, next generation space telescopes, the space station as an engineering center, human exploration, and environmental modeling. To do so, we'll need broad industry and academic involvement. That's a cultural barrier, because this is not just about the aerospace industry. It is not just about technology. It's about people and how people work and communicate on a global scale to enrich our lives. Perhaps most of all, it's about education.

Back when we were using slide rules, people referred to the Three R's. Now we need the Three I's: information, integration and infrastructure.

Information: Engineers need more of it, or at least more of the right kind. Today's engineers can use the "black box," but they didn't build it. Because they didn't build it, they have trouble understanding the limiting first principle assumption of how it works, which leads to design and application failures. It's not that we have bad people; our teachers and students are the best. We're just guilty of using old approaches in a new era.

DENNIS VANDAL

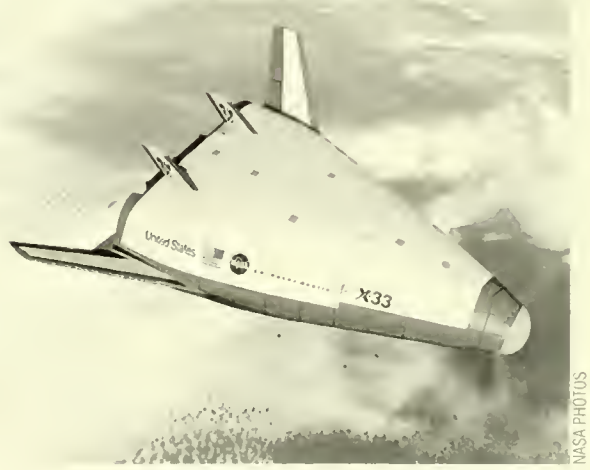
Integration: We need to do more to integrate the most rapidly advancing fields in engineering education, such as biology. We are on the cusp of the Biological Revolution, and it's leaving engineering in its wake. We've seen how the knowledge explosion in the biological sciences, particularly in areas like health care and agriculture, has changed the way we live. The engineering community can't afford to sleep through this revolution.

We must take the intellectual underpinning of biology and apply it to engineering. Some call this biomimetics. I've referred to the power of the human brain. A single brain cell can carry 10 times as much information as today's most powerful computer and it is much more energy efficient. The engineering sciences need to apply this capability. We must understand, appreciate, integrate and exploit biological processes and their incredible potential. Our goals at NASA depend on that, as does the future of engineering. This is something our education system must reflect.

Infrastructure: Government, universities and industry must realize that our educational infrastructure can no longer be bricks and mortar; it must be bits and bytes. This means we must initiate and support revolutionary changes in our university engineering programs and create new capability for lifelong learning.

NASA and government must continue to push the envelope with long-term, high-risk research. We must work with industry to translate research concepts into workable methods and products. Most of all, we must bring in universities as fundamental, intellectual participants in the development of technology crucial for the ISE vision. NASA is already planning a program to do just that.

Industry must also support not just operations and near-term product development, but long-term, high-risk research and development. We'd like industry to work with us to create the workforce of the future, one that is not only more flexible, but that recognizes creativity and has a deeper understanding of the systems and tools it develops and uses.



NASA PHOTOS

Smarter control systems, superfast planes that will cut in half travel time across the Pacific, and new generations of reusable spacecraft, like the X-33, are elements of NASA's 25-year plan. But Goldin told the members of IUGREEE that this plan—and the technological supremacy of the nation—will depend on the work they and others are doing to revolutionize technological education.

And universities must understand this changing environment and develop new curricula and research capabilities. This is absolutely crucial because it is tomorrow's engineers who will enable everything I've discussed in this essay. With his invention of the liquid-fueled rocket, Robert H. Goddard, a 1908 WPI graduate, launched the Space Age. Future Goddards may pilot a submarine beneath the icy ocean we think covers Europa. Others may build a colony on Mars. They will have the training, the understanding and the tools. But only if we work together. So let's get to work.

—Goldin is administrator of the National Aeronautics and Space Administration (NASA). This article is adapted from Goldin's keynote address to members of the Industry/University/Government Roundtable on Enhancing Engineering Education, who met at WPI in May.

MAKING BIG PLANS

By
Edward A. Parrish

On Nov. 11, 1868, WPI inaugurated its first president and dedicated its first building with a long day of oratory by leaders from government and education. Among the speakers was John S. Woodman, head of the Chandler Scientific School at Dartmouth, who offered some well-considered words of advice to the leaders of the new Institute. He said a good college needs money, excellent teachers and wisdom, with the last item being the hardest to find.

"Wisdom," he said, "is needed to adjust plans and aims to means; to find the highest and best things; to aim only at just what can be well accomplished; to keep out of the way secondary, inferior and outside matters, that the money and the labor may all count upon the vigor and efficiency of the few great, central objects; and that the character of the institution may be steady, growing, and permanent."

WPI has spent the past few years in search of just that sort of wisdom. We are seeking to adjust our plans and aims, to find the highest and best things to which we can aspire, to devote our energies to the work we can do well, and to focus our imaginations on ideas and new initiatives that will help WPI grow steadily in excellence and reputation. In short, we are trying to make the big plans that Daniel Burnham talked about, and not the little plans that would result in our doing only a little better what we already do.

Big plans for WPI's future are emerging on a number of fronts. Building on the groundwork of the Strategic Planning Steering Committee of 1996-97, the Planning and Implementation Committee has been developing a number of strategic goals that it will present to the community this fall (see *The Wire*, June 1998). Concurrently, the provost has involved the academic departments in a self-study that will help identify new thrust areas that build on WPI's strengths and respond to the needs of a rapidly changing world. And the Alumni Association is drafting a new master plan that will be a blueprint for engaging, informing and serving our graduates in the decades ahead.

A Strong Foundation

All of these plans are being built on a foundation of knowledge about WPI's current position, the opportunities before it, and the threats and opportunities it faces at home and in the world beyond the campus. Here's a look at that foundation.

First, our current situation. One of WPI's greatest strengths is its excellent faculty. The faculty is the heart and soul of our outstanding education and research programs, and they bring national and international recognition to WPI as they are honored with major external awards and grants, election to fellow status in professional societies, invitations to speak at many national venues, and so on.

Provost Jack Carney and our academic departments invest a great amount of time and effort each year recruiting the very best educa-

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"Make no little plans. They have no magic with which to stir men's blood and probably themselves will not be realized. Make big plans: aim high in hope and work. Remember that our sons and grandsons will do things that would stagger us. Remember that when you create a situation that captures the imagination, you capture life, reason, everything."

Architect Daniel Burnham
whose work included New York's Pennsylvania Station
and Union Station in Washington, D.C.

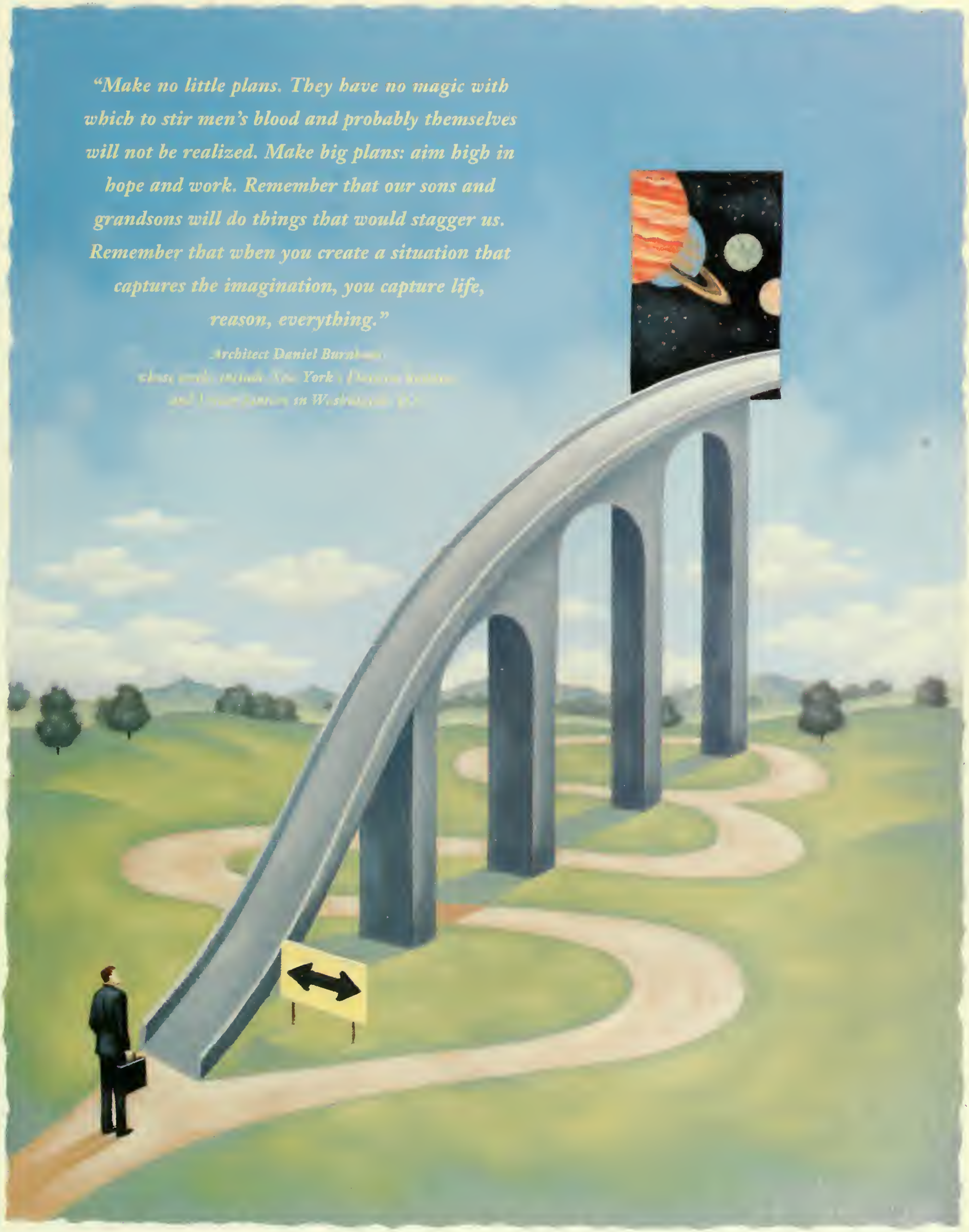


ILLUSTRATION BY FRED LYNCH

Kings of the Road

More than 40 years ago, the federal government authorized the construction of a modern engineering miracle, the interstate highway system. Today, over 42,000 miles of controlled access highways in 49 states form a vast interconnected transportation system that spans the nation. Four WPI graduates played important roles in building a modern highway system in Massachusetts.

PATRICK O'CONNOR

As early as the 1920s,

it was becoming apparent that America's love affair with the automobile would give rise to a demand for a new class of roadway, one that could accommodate a constantly growing volume of vehicles and our desire to travel ever farther and faster. In the following two decades, the superhighway was born. The success of its early incarnations, including the parkways of greater New York and the Pennsylvania Turnpike, led planners to envision a national network of four-lane, divided highways to whisk motorists from coast to coast.

BY RUTH TRASK

World War II put plans for a national highway system on hold, but the return of GI's from overseas and the colossal spending spree that followed put even more cars and trucks on the road and exerted an even greater strain on the nation's aging roadways. In addition, the beginning of the Cold War placed a new focus on the need for rapid military deployment. A network of high-volume, limited access highways, it was believed, would be an ideal way to move men and equipment quickly from place to place in times of national crisis.

In 1944, Congress approved the establishment of the Interstate Highway System, though it would be another 12 years before work on the system began. On June 29, 1956, President Eisenhower signed the Federal Aid Highway Act, which called for the construction of 41,000 miles of modern highways across the country (later legislation increased that total to 42,500, and further additions brought the actual total built to 42,700). The system, eventually known as the Dwight D. Eisenhower System of Interstate and Defense Highways, would encompass every state but Alaska and take nearly three decades to complete (a few segments have yet to be built). About 90 percent of the cost of the system would come from federal user fees (gasoline taxes), with the balance coming from state coffers.

Encouraged by the ready availability of federal funds, states embarked upon an unprecedented period of road building beginning in the 1950s. Massachusetts was no exception. Working in the state's Department of Public Works, the Massachusetts Highway Department and other agencies, a number of WPI graduates helped plan, build and maintain the ribbons of asphalt, concrete and steel that today constitute the state's modern and indispensable ground transportation network. Here are the stories of four of those master road builders.

The interstate system is one of the great engineering marvels of modern day civilization," Dean Amidon says. During the early 1960s, he was directly involved in the construction of one component of that marvel, Interstate 91, which traverses three New England states. Amidon was in charge of three projects on the portion of I-91 that passes through Springfield, Mass. "I found the projects challenging, but enjoyable," he says. "Building, making changes and seeing the results of our work made my I-91 assignment one of the high points of my career."

Amidon says construction of I-91 was fraught with obstacles. At one point, after the bridges for the project were nearly finished, the federal government forwarded new national defense requirements stipulating that bridge clearances be raised from 14 1/2 feet to 16 feet. Other change orders required that drainage and utilities and partially finished roadwork at a complicated interchange be redesigned and rebuilt. "We handled change orders right on the job as we received them," Amidon says. "There was very little delay."

Today, Amidon looks at I-91 and the rest of the interstate system with a feeling of accomplishment. "As I drive interstate highways throughout the country," he says, "I realize what a tremendous change the system has brought to people's lives, not only in terms of driving safety, but in terms of freedom of movement and choice of lifestyle. I'm pleased to have played a part in bringing those changes about."

More than a decade before he helped build I-91, Amidon joined the Massachusetts Department of Public Works as a junior civil engineer in Berkshire County. One of his earliest assignments was helping restore bridges wiped out

(Continued on page 24)

Dean P. Amidon '49

Career: 36 years with the Massachusetts Department of Public Works, three of those as commissioner; retired in 1987.

Today: Senior associate and consulting engineer at H. W. Lochner Inc.

KINGS OF THE ROAD

(Continued from page 23)

during a flood in 1949. He worked on highway and bridge construction projects in the Connecticut Valley briefly, beginning in 1955, before returning to the Berkshires, where his assignments included the construction of State Route 116 from Amherst to North Adams. For a time, he worked in Boston as the DPW's locations and survey engineer and also developed Massachusetts' implementation of TOPICS (Traffic Operations Program to Improve Capacity and Safety), a federal initiative aimed at increasing the use of traffic engineering techniques to improve the efficiency of urban highway systems.

In 1969, Amidon was named district highway engineer in the Lenox office, where he was responsible for all facets of public works in the district, including design, structures, environment, traffic engineering, maintenance, construction, administration and public relations. He was named DPW commissioner a decade later, overseeing a department with 4,100 employees and an annual operating budget of $100 million. After a three-year term as commissioner, he returned to his District One post in Lenox.

One highway project overshadowed Amidon's career in the Berkshires. Called the Route 7 or Pittsfield Bypass, the proposed limited-access highway would have relieved traffic congestion on State Route 7 between Lenox and Pittsfield. Amidon remains a champion of the project.

"New highways and bypasses are the same as jails, dumps and incinerators," he told the *Berkshire Eagle* in 1987. "We know we have to have them. Someone has to have the guts to make a decision—to say, 'Yes, it's going to hurt some people, but it's going to help more people, so let's do it.'" A final decision on the bypass project is still pending.

John F. Gallagher '50

Career: 42 years in varying engineering assignments with the Massachusetts Department of Public Works and the Massachusetts Highway Department; retired in 1992 as associate commissioner.

Today: Transportation liaison between the Massachusetts Highway Department and other state and federal transportation agencies; transportation consultant for Cullinan's Project Managers in Auburn, Mass.

Highly regarded in his field, Amidon was recognized in 1975 for his engineering and administrative abilities when he received the Engineer of the Year Award from the Berkshire Chapter of the Massachusetts Society of Professional Engineers. In 1980 the American Public Works Association named him one of the Top Ten Public Works Leaders of the Year in the U.S. and Canada.

Two years later, he was elected president of the Northeast Association of State Highway and Transportation Officials, which covers the six New England States, Delaware, Maryland, Pennsylvania, New York, the District of Columbia, Puerto Rico, the Virgin Islands and five provinces in Canada. Its mission is to set standards for transportation design and construction nationally and to foster development, operation and maintenance of an integrated national transportation system. Most recently, he received the annual Outstanding Highway Official Award from the Massachusetts Highway Association.

Amidon can look back with pride at a career in which he has supervised a lengthy list of construction projects, from new bridges to road improvements to new highways. But he says his greatest thrill is seeing the products of his labor fulfilling their intended functions. "I look at a bridge or a road I've built, and I tell myself, 'That's real.' That stays with you forever."

It's almost impossible to drive on a major highway or cross a bridge in Central Massachusetts that doesn't bear the stamp of approval of Jack Gallagher. After graduating from WPI in 1950 with a bachelor's degree in civil engineering, Gallagher accepted a post as construction engineer with the Massachusetts Department of Public Works, and went on to serve as assistant district traffic engineer and assistant project engineer in the Massachusetts Highway Department. In the latter post, he was placed on special assignment to work on the design and rebuilding of 100 bridges damaged or destroyed in flooding during Hurricane Diane in August 1955.

From 1956 to 1964, he was assistant construction engineer and a part-time project design engineer. During that time he designed Lake Avenue in Worcester and Route 122 from Tatnuck Square in Worcester to the Paxton town line. By the late 1950s and early 1960s, the road building boom had created a need for young engineers skilled in highway design and construction. To help fill the need, Gallagher and several other WPI alumni taught courses in highway engineering, fluid mechanics, reinforced concrete design and related topics at the former Worcester Junior College.

In February 1968, Gallagher, having risen to the post of assistant chief engineer, found himself speaking before citizens' groups about Interstate 190, a new route designed to reduce travel time from Worcester to Leominster and other points north. "There was some concern in West Boylston," he recalls. "People were afraid that the new superhighway would seriously divide the town, though it didn't."

Ultimately, I-190 became part of what is sometimes called the North-South Freeway, one of the state's most important traffic arteries. Also consisting of portions of I-290 and I-395, the freeway joins Fitchburg in the north and Webster in the south.

The I-290 project, also called the Worcester Expressway, was the site of a major construction accident in 1968, Gallagher remembers. In April, a bridge being built over a section of Southbridge Street in Worcester collapsed, killing three construction workers and injuring eight. Media reports noted that only one end of the steel girders had been fastened to the concrete abutment, but Gallagher told reporters the technique is standard practice to prevent expansion

and contraction of the beams from ripping out the bolts. A general inquiry into the collapse ruled out negligence, but was unable to pinpoint a specific cause, Gallagher says. Just five months after the bridge disaster, the southern leg of the expressway, from Brosnihan Square to Route 20 in Auburn, was opened.

Beginning in 1970, Gallagher took a three-year post as assistant director of the newly established Massachusetts Bureau of Solid Waste before returning to the Highway Department as project development engineer. In that capacity, he worked with officials in towns along the route for the proposed I-395. In Webster, he helped win approval for a ramp to connect the town to the highway. In Auburn, he discussed possible routes the road might take through town and made sure residents had a voice in planning for landscaping and sound-reducing barriers. A former chairman of the Auburn Planning Board, Gallagher also urged the town to use zoning as a tool for planning for the growth the new highway would bring.

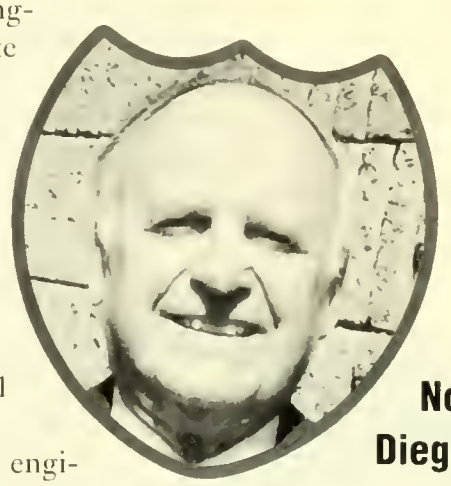
Promoted to deputy chief engineer of highway maintenance in 1987, Gallagher supervised a staff of more than 250, as well as another 1,000 workers who completed work for the department. For the next five years, until his retirement, he was responsible for the upkeep of 13,000 lane miles of highway and more than 2,800 bridges. "Fighting for maintenance funding was my biggest concern," he says.

"In my present consulting work, I haven't lost contact with the state highway department," he adds. "I still enjoy meeting with city and town officials to advise them on transportation problems. I'm proud to have been part of building and maintaining the interstate highway system, a part of my career for which my WPI education and the excellent WPI professors prepared me quite well."

Back in 1953, a reporter for the *Boston Sunday Globe* took a jeep ride with Norm Diegoli through the wilds of Cape Cod near Provincetown, where the state was building a section of the Mid-Cape Highway. Noting that Diegoli steered the vehicle deftly "through this wilderness of near-rootless scrub pines, stunted bushes and pure sand," the writer observed that Diegoli could make the jeep do everything but wait on tables. That's also a good summary of his varied career with the Massachusetts Department of Public Works and the state Highway Department.

After earning his degree in mechanical engineering (he would later graduate from Stanford University under the U.S. Army's Specialized Training Program for Advanced Engineering), he started out working on the design, construction and maintenance of the state highway/interstate highway network. His initial assignments included the construction of several sections of State Route 6 from the Cape Cod Canal to Provincetown, State Route 24 from Taunton to Fall River, and State Route 3 from Duxbury to Hanover.

During the early years of his career he was also "on loan" to the U.S. Navy for bridge construction at the Hingham Navy Yard and to the State Division of Beaches for the construction of Scusset Beach Reservation at the east end of the Cape Cod Canal. In 1968 he was transferred to the Bureau of Transportation Planning and Development, where the corridors for Interstates 495, 190, 391 and 392 were worked out.



Norman L. Diegoli '48

Career: 34 years with the Massachusetts Department of Public Works and Massachusetts Highway Department, including a term as deputy chief engineer for the DPW's Division of Waterways; retired in 1983.

Today: Senior interstate representative for Bartlett Consolidated Inc., a maker of traffic signal devices, highway signs and guard rails in Plymouth, Mass.

Promoted to deputy chief engineer of the Division of Waterways in 1974, he oversaw the rebuilding of state piers in Plymouth, Fall River, New Bedford and Gloucester. During his watch, the canopy that encloses Plymouth Rock was extensively refurbished and a number of state harbors and waterways were dredged.

Diegoli was the last deputy chief engineer for the Division of Waterways, as the division became part of the Office of Environmental Affairs in a 1977 reorganization. He transferred to the state Highway Department as deputy chief engineer in the Division of Maintenance and Equipment, and had barely settled into his chair when state employees launched what would become a three-day strike. From his command post in the Communications Office, he saw to it that drawbridges continued to operate, traffic lights were in working order, and emergency highway repairs were performed, despite the walkout. "We were grateful," he says, "for the help given us during the crisis by sympathetic contractors, municipal electricians and faithful state employees who used their own vehicles to render services after dark."

Another, more daunting crisis arrived the following year. On Feb. 6, 1978, New England was hit by one of the worst blizzards of the century. Diegoli says the day took on a note of tragedy even before the storm hit when a passing motorist on Route 1 in Dedham struck and killed a state maintenance worker. That afternoon, the snow started and conditions on the state's roads quickly deteriorated. For the next two days, most highways were impassable.

Diegoli says 2,800 vehicles were stranded on just one stretch of Route 128, between Route 9 in Wellesley and Route 138 in Canton. With crews from Vermont, New Hampshire and the U.S. Army assisting, clean-up operations continued around the clock until Feb. 11, when the last section of Route 138 in Stoughton opened to traffic once again.

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KINGS OF THE ROAD

(Continued from page 25)

The snowy winter of 1978 was followed by a long, hot summer that found Diegoli in Cape Canaveral, Fla., overseeing the completion and testing of a high-speed hovercraft commuter boat. "That fall, the hovercraft was put into service between Hingham and Boston," he says. "But soon, service had to be curtailed because the craft kept running into floating debris, causing accidents."

Late in his career, Diegoli put his skills as a first-rate problem-solver to work on yet another challenge: cutting red tape in his own department. "I designed a program in which insurance companies pay for repairing damage to state highway property caused by motor vehicles," he says. "The program ensures that repairs are made quickly even during times of severe budget cuts and resource restrictions."

Ellsworth M. Sammet '49

Career: Four decades with the Massachusetts Department of Public Works, including two stints as district highway engineer; retired in 1989.

Today: Enjoying retirement in Pittsfield, Mass.

During a career spanning 40 years, there is bound to be at least one assignment that stands head and shoulders above the rest. For Sam Sammet, that special assignment was working on the construction of Interstate 91, a highway that now carries motorists from New Haven, Conn., to the Canadian border in Vermont. As assistant district construction engineer in District 2 in Northampton from 1965 to 1970, Sammet supervised resident engineers working on sections of I-91 from Greenfield, Mass., south to Chicopee and Springfield, including the link between I-91 and Interstate 291 in Springfield.

"Construction of I-91 along the Connecticut River Valley was especially challenging because many sections required construction in two phases," he says. The unusual technique, he notes, was necessary because of the thick layers of clay and silt along the river. In the first phase, embankments were built several feet above their final grade and allowed to settle for 18 to 24 months while the elevation of the road was monitored using settlement platforms and piezometers (instruments that measure pressure and compressibility).

To add to the complexity of the project, construction of drainage culverts had to reflect the anticipated settlement and bridges could not be constructed until the roadways had reached their final grades. "Building I-91 was one challenge after another," Sammet says. "But in the end, it was worth it."

Sammet joined the DPW in 1950 as resident engineer on highway and bridge projects in District 3, which encompasses Worcester County. He remained in that post for 15 years, working principally on sections of State Route 2 in Westminster, Gardner, Phillipston and Athol. After I-91 was completed in 1970, he was promoted to District 2 maintenance engineer in charge of all district highways and bridges.

At the time, plans were being made for the $90 million Route 7 Bypass project in Pittsfield. Expecting that construction would start in 1972, Sammet accepted the post of District One construction engineer and moved to Pittsfield in 1971. But the project never got off the drawing board. Sammet says he believes the price tag for the project has grown so high that it is unlikely to be built any time soon, especially since the "Big Dig" in Boston is siphoning off most new construction funds.

One of the factors that helped sidetrack the bypass, Sammet says, was the opposition of hundreds of homeowners in its path, who would, of necessity, have had to give up their houses. The District One construction engineer found himself caught in the crossfire between irate homeowners and the administration of Governor Michael Dukakis, which had pushed for the funding for the bypass and wanted it built. While he sympathized with the homeowners, the proposal had been on the table for 40 years and he felt it was time to build it to improve the regional transportation system.

As district chief, Sammet also monitored millions of dollars allocated by the state for highway building and maintenance in Berkshire County and eight contiguous towns, an assignment that entailed coordinating with 38 diverse boards of selectmen and two mayors. Commenting on the even temperament Sammet needed to do his job, one local reporter wrote that he was "a chief engineer with a bedside manner."

When Dean Amidon '49 was named commissioner of the State Department of Public Works in 1979, Sammet assumed the post of district highway engineer, a position he held until Amidon returned to the district in 1981. For the next six years, Sammet served once again as district construction engineer, taking on the additional duties of assistant district highway engineer. With Amidon's retirement in 1987, Sammet returned to the district highway engineer's chair until his own retirement in 1989. At his retirement luncheon, it was noted that Sammet was responsible for the substantial progress that had been made in updating, reconstructing and rehabilitating the state and town transportation system in his district.

As he looks back over a "very satisfying career in civil engineering that was launched at WPI," Sammet says he is particularly proud of the many miles of highways and the more than 100 bridges that exist today, in large part, because of his supervision. "Although highways and bridges often bear the names of politicians who helped fund them," he says, "the real imprint is that of the engineers and contractors who designed and built them." ■

—Trask, former alumni news editor for WPI, is now a freelance writer and a frequent contributor to the Journal *and* The Wire.

Making Big Plans

(Continued from page 20)

tors and researchers. Their labors, coupled with WPI's growing reputation, have enabled us to attract some outstanding new faculty members to our campus in recent years. This fall, we welcome 17 faculty members, including new chairs for the Chemical Engineering and Computer Science departments. In addition, Malcolm Ray, the first recipient of the White Family Endowed Professorship in Civil Engineering, a gift of Leonard H. White '41 and his family, will arrive in January. I am impressed by the extraordinary credentials of this group of educators and scholars who come to WPI from many of the nation's finest universities.

Of the tenure-track faculty who've just joined us, two are in computer science and three are in mathematical sciences—areas where average class size has been large enough to get in the way of the close student-faculty interactions that are the hallmark of our programs. We are committed to adding still more tenure-track faculty in the years ahead.

There are many factors to consider when hiring new faculty members. We seek excellent educators with a commitment to students, accomplished researchers with interests that make a positive contribution to our overall research program, and individuals who will thrive in our particular environment. Recognizing that our faculty members can be powerful role models for our students, we also want a faculty that reflects the diversity of our student population. While there is more work to be done, we are pleased that of the 44 faculty members hired over the past 3 ½ years, 11 are women and 14 are minorities.

We also have a dedicated staff and we have bright students, enrolled in about the right numbers and supported by several strong student services that promote retention, wellness, leadership and career planning. We have been working over the summer to enhance some of those services. Recognizing our obligation to support the growing student interest in overseas projects (see below), we have created more elbowroom in the Project Center for the Global Perspective Program. Since oral and written communications are such critical elements of project work at WPI, we've moved the Writing Resource Center to the Project Center. We've also created the Learning Center, whose mission is to help students develop positive learning skills.

One of WPI's most critical support services is the George C. Gordon Library. For the past three decades, our library has served well the needs of our students and faculty. Today, with nearly 350,000 bound volumes, more that 1,000 current journal subscriptions, hundreds of electronic resources and databases, and links through the Internet to information resources throughout the world, Gordon Library is a well-equipped research facility. But it is under two serious constraints. The first is space. The growth in the library's holdings and in the demands placed upon the facility by active research and project programs has left it in need of additional room. The other constraint is money. Rapidly rising prices for journals—print and electronic—have outpaced the growth in the library budget. Eliminating underused titles has helped, but we are still fighting an uphill battle with journal prices. In the short term, we've increased the library's journal budget for this year. With the aid of our strategic planning process, we hope to find long-term solutions to the space and money crunches.

WPI also has a well-maintained physical plant soon to be expanded through the construction of a 71,000-square-foot campus center, a 41,000-square-foot academic building, and an adjacent parking garage. In recent months we have enhanced our physical facilities through a multitude of construction projects. For example, we completely renovated Daniels Hall. The project is part of a $14 million program to refurbish and modernize four of WPI's residence facilities by the fall of 1999. Renovation and construction projects provided new and enhanced facilities for research in biology and biotechnology, biomedical engineering, chemical engineering, chemistry, and electrical and computer engineering. We made some of our academic buildings more accessible to the handicapped, spruced up the properties we own in the surrounding neighborhood, and remodeled the first floor of Boynton Hall and the entrance to the Admissions Office to provide a more attractive entryway for visitors.

"We seek excellent educators with a commitment to students, accomplished researchers with interests that make a positive contribution to our overall research program, and individuals who will thrive in our particular environment."

But one of the most exciting projects involved renovations to our classrooms. In recent years, WPI has created a number of state-of-the-art multimedia classrooms with computers, video technology and satellite links. Over the summer, we added another, Stratton Hall 203, which was transformed into a computer classroom for mathematics education. Six other classrooms in

(Continued on page 28)

MAKING BIG PLANS

(Continued from page 27)

Stratton were renovated and outfitted with new seating, ceilings, lighting and carpeting. Two classrooms in Salisbury Laboratories were also renovated, and new seating was installed in classrooms in Higgins Labs and Olin Hall.

Creating well-equipped, networked classrooms is just one aspect of WPI's commitment to giving members of our community the information tools and resources they need for teaching and learning. We've made significant investments over the past few years in our information infrastructure, for example, placing network connections in every residence hall room and installing wireless network links to our fraternities and sororities. This summer we increased the speed of our residence hall connections from 10 megahertz to 100 megahertz to help resident students keep pace with the growing multimedia capabilities of the World Wide Web. We also upgraded network connections in 11 academic buildings.

"The gains in maturity and self-confidence students realize through their global experience are among the important characteristics that distinguish overseas projects, as a group, from those completed here on campus."

WPI has many other strengths, of course. For example, the market value of its endowment and similar funds is now $254 million, and this fall *U.S. News & World Report* ranked the University No. 51 among the top universities in the nation and 18th in terms of the quality of educational programs based upon cost of attendance. But some of our most significant assets as the end of the 20th century approaches may well be the remarkable opportunities that lie before us.

A UNIQUE MOMENT IN TIME

The University is slowly gaining a national reputation and is experiencing a gradual increase in prestige. We have an established product that is in high demand and an undergraduate academic program, the WPI Plan, that anticipated by 25 years a number of national initiatives in technological education reform. In addition, our unique society and technology project (the IQP) and the potential applicability of the WPI Plan to graduate education are strong advantages.

WPI has taken a significant lead in providing students global opportunities; we have also realized great success over the past year in marketing our remarkable Global Perspective Program to our own students. Last year the Global Ambassadors, students who are veterans of overseas project work, took advantage of every opportunity to tell other students about the academic, professional and personal benefits of working on projects in other cultures. Largely as a result of their efforts, interest in the global projects program ballooned. This year we are taking steps to accommodate the many students—about half of our junior class—who wish to complete projects at our overseas sites. Our project center directors have been working with current and potential project sponsors to identify new projects. We have also been expanding our operations at some centers and working to create new ones. We will inaugurate centers in Boston, Copenhagen and Melbourne in 1998-99 and offer project opportunities in Zimbabwe next summer.

We are bolstering our efforts to prepare more faculty to serve as overseas project advisors. This is arguably one of the most demanding jobs our faculty do. Overseas advisors are on duty around the clock for seven weeks straight, dealing with the academic and social needs of students who are often thousands of miles from home and familiar surroundings. The job is not without rewards, of course, the greatest of which is seeing the remarkable personal growth students undergo at these centers.

The gains in maturity and self-confidence students realize through their global experience are among the important characteristics that distinguish overseas projects, as a group, from those completed here on campus. One of our priorities as an institution is to find ways to give students who complete their required projects locally the opportunity to realize the excitement, educational benefits and personal rewards of off-campus project work. Toward that end, we will work this year to establish and raise funds for the Worcester Project Center, where students will conduct IQPs with local agencies. The center will have as part of its mission consolidating and enhancing the services our students perform for the local community—through their projects and as volunteers. We believe that this exciting new program will enrich our educational programs and make a positive contribution to the city WPI has called home for over 130 years.

Along with those opportunities comes a host of threats that we must take quite seriously. For example, national engineering reform efforts, supported by more than $120 million in federal government funding, could remove our competitive advantage and erode the value added by the WPI Plan. Just as important, the high workloads of WPI faculty and staff make it difficult to continuously improve, which we must do to remain competitive, and even threaten our current quality.

The fact is, we've reached an inflection point, a time where we will need to decide whether we climb up, or slide down. I believe it's time to make a change—time for a great leap forward that will

enable us to scale new heights of recognition and success. Historically, change occurs inadvertently; you don't see it coming. But we must either shape change, or it will shape us. British novelist Graham Greene spoke of a "unique moment in time when the door opens and lets the future in." I think we've arrived at such a moment.

Reality vs. Perception

Our great leap forward should also help address WPI's image problem. The quality of our program is high, but our prestige is not commensurate with that quality. For example, while *U.S. News & World Report* ranked WPI among the top 51 universities in the nation, it also said our academic reputation, while improving, was among the lowest of those 51 schools. Academic reputation is about prestige, not quality.

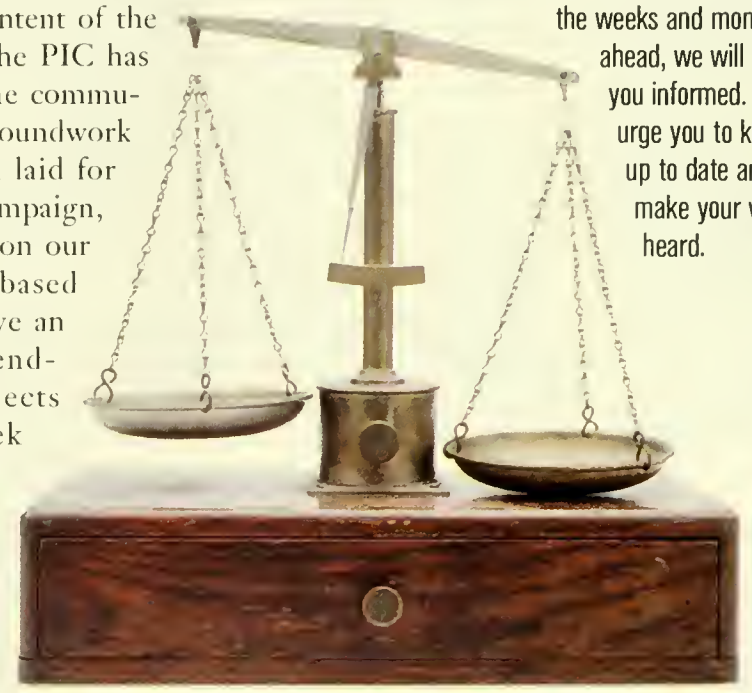
We need to make a change that will increase our quality *and* prestige, and we need to do it while we are still in the national spotlight. The spotlight is on us for a number of reasons. One, of course, is our *U.S. News* ranking. Another is our selection as one of the first two universities in the nation to have their engineering programs accredited under the new outcomes-based criteria adopted by the Accreditation Board for Engineering and Technology. The criteria will soon apply to every engineering program in the nation, so there are hundreds of colleges and universities that want to know about our experience and our academic programs. Another reason for the spotlight was the decision of the Industry/University/Government Roundtable on Enhancing Engineering Education to hold a major meeting at WPI in May, its first meeting ever on a university campus. [NASA Administrator Daniel Goldin was the keynote speaker—see page 16 for his remarks.]

This is the right time to make a leap. Interest in WPI is at an all-time high. Our academic programs are in demand and we're attracting record applicant pools, and our applicants require less financial aid than in previous years. Our new class, the Class of 2002, is a good case in point. Starting with the largest applicant pool in the University's history, we expect to enroll between 680 and 690 students, comfortably above our target of 675. As I write this article (before students matriculated), the class includes 22 valedictorians and 12 salutatorians. A total of 46 percent are in the top 10 percent of their high school classes. Twenty-two percent of class members are women and nearly 6 percent are minority students.

Just as we have had great success in attracting outstanding students to our campus, our graduates are finding the kind of employment for which they've prepared. The economy is strong. The jobless rate is at a 24-year low, and twice as many high-paying jobs are being created as low-paying jobs. There is an especially strong demand for employees in engineering, management and computer services—our programs. In fact, Congress is so concerned about the lack of technical skills in the U.S. workforce that it is thinking about increasing the quota for immigrants with technical skills from 65,000 to 105,000 a year to fill the void. I'd like to help fill that void with our graduates.

Making the Leap

So, just what will constitute the great leap forward I've alluded to? The answer to that question is gradually emerging and will become clear when the Planning and Implementation Committee makes its final report to the community in late October (culminating a planning process that has involved dozens of faculty and staff members, students and alumni) and as the self-study being conducted by the provost and academic departments is completed.



Judging by the content of the draft initiatives that the PIC has already shared with the community and the initial groundwork that has already been laid for WPI's next capital campaign, the leap will build upon our trailblazing project-based curriculum and involve an expansion of our trend-setting global projects program. It will seek to revitalize and expand research at both the graduate and undergraduate levels, while redoubling our emphases on teaching and learning, lifelong learning, and outreach programs. It will include the exploration of new ways of integrating learning and living through innovative residential communities, as well as the strategic expansion and renewal of our campus, including the construction of the new campus center, academic building and parking facility.

Making a significant leap forward will take considerable resources. Much of this fiscal fuel will come from the upcoming campaign. Many institutions use their campaigns to make incremental changes. But if WPI takes that approach, I believe it will become a traditional institution and will lose its edge in project-based programs, in global programs, and in the other features and characteristics that make this university distinctive.

This is an opportunity that occurs rarely in the life of an institution. The prestige we will gain and the immediate and much-needed investments we will make will help WPI become a true national university—and sooner, rather than later. ■

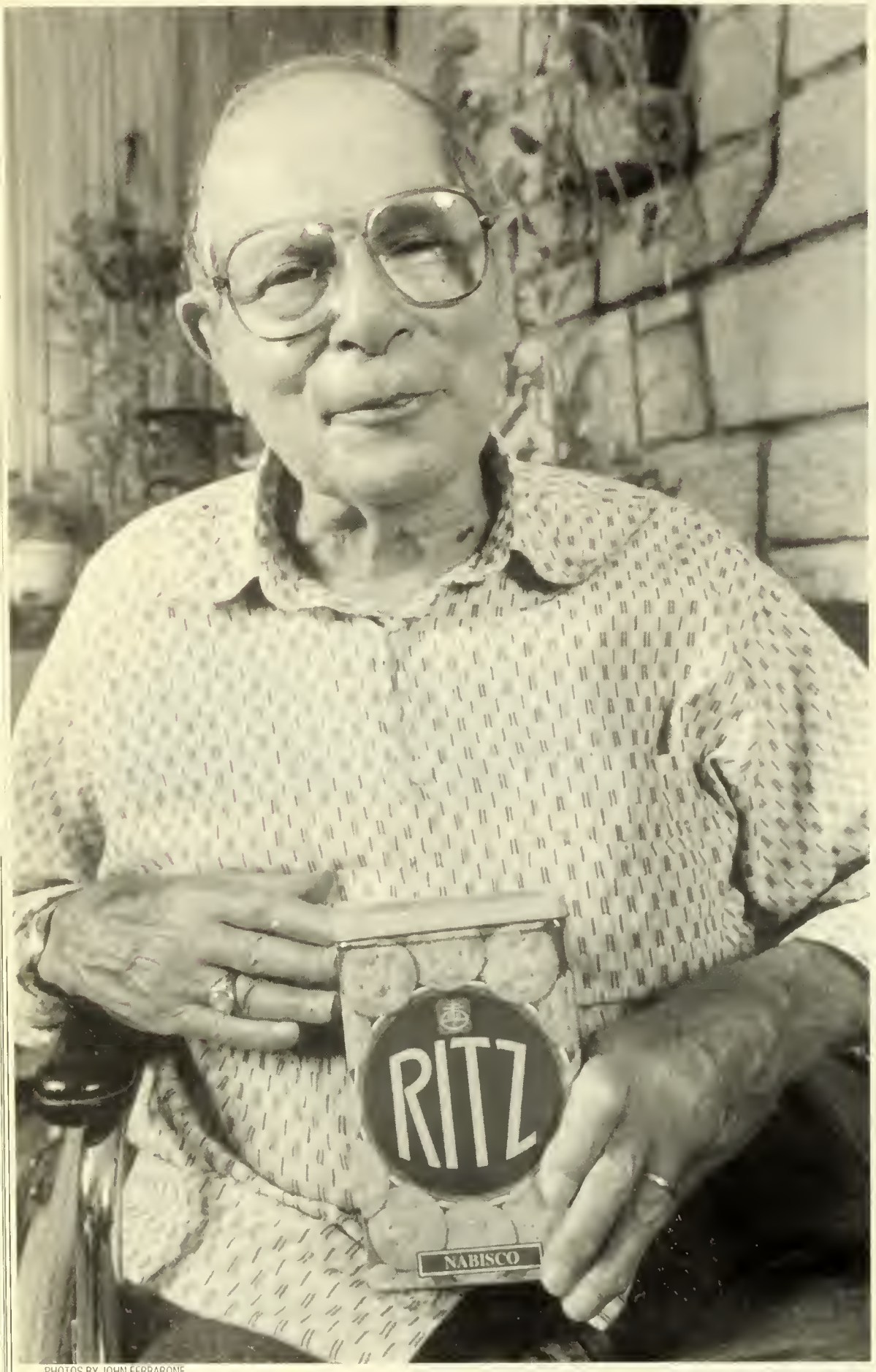
—This article is based on the State of the University *address that President Parrish delivered to the WPI community on March 11, 1998, and on his recent progress report to the WPI faculty, staff and students.*

Make Your Voice Heard

It will take more than money to propel this institution forward. It will take the interest, involvement and support of all sectors of the greater WPI community. As our plans for the future take shape in the weeks and months ahead, we will keep you informed. I urge you to keep up to date and to make your voice heard.

An important opportunity to speak out is coming up quite soon. Starting in the last week of October and continuing to mid-November, you will have the chance to register your opinion on the PIC's proposal and indicate how you would prioritize the committee's recommended goals. To cast your vote, visit WPI's strategic planning Web site (www.wpi.edu/Stratplan/), read the final PIC report once it is posted, and take part in an innovative Web voting system. If you are unable to use the Web, call the Communications Group at 508-831-5305 and a paper ballot will be faxed or mailed to you. The Planning and Implementation Committee very much wants to hear from all sectors of the WPI community, so please take part.

A Grand Tradition



PHOTOS BY JOHN FERRARONE

BY CHET WILLIAMSON

The gift that keeps on giving can arrive in many forms and have many meanings. For 82-year-old Henry M. Ritz '38, it was a music box he received a half century ago. From that first magical, mechanical device has grown an impressive collection that numbers more than 150 music boxes from around the world.

"It was something that just grew on me," says the retired president, treasurer and CEO of R&R Plumbing Supply Corp. in Worcester. "When R&R moved from Mechanic Street to Worcester Center Boulevard, I received a cigarette holder that played music. That started me off. Thereafter, on my birthday or Father's Day, my friends, my relatives and my children would give me music boxes."

The bulk of the Ritz collection is housed in a large, lighted cabinet in the basement of his home. Music boxes of every shape, color and nationality are crowded yet neatly arranged on shelves behind a glass encasement. A trolley car clangs out "I Left My Heart in San Francisco." A miniature Russian church plays the ancient folk song "Troika." A tiny gramophone twinkles "The Way We Were," and a Parisian kiosk plastered with French posters renders "La Moulin Rouge."

There are music boxes disguised as pocketbooks, radios, wristwatches and musical instruments. There are many wine and liquor bottles: an amber one plays "Little Brown Jug," while another spills out "How Dry I Am." One box, designed to look like a package of Ritz Crackers, has no doubt launched a thousand conversations at the Ritz household as it tapped out "Puttin' on the Ritz."

Other boxes set in motion twirling dancers, chirping birds and blowing whistles. There are musical buildings, alarm clocks, pin cushions, cigarette lighters, perfume atomizers, makeup cases, baseballs, footballs and banks. A birthday cake, in celebratory fashion, tinkles "Happy Birthday."

It's been said that when a music box is played in a room full of people, "everything else will stop." Ritz agrees. "It has a special tone," he says. "You can turn on a radio and people won't stop. A CD? People won't stop. But a music box? They do. It's like you are going to a circus and hearing a calliope."

"Music box," according to the Musical Box Society, an international educational organization, is a popular term "covering all types of automatically played musical machines, from small tabletop instruments that use a cylinder or disc to play tunes on a steel musical comb, to large orchestrions [mechanical band pianos] and carousel organs which have the musical capability of a symphony orchestra or a military brass band!"

The Encyclopedia of Collectibles dates the oldest music boxes to the last quarter of the 18th Century, "when watchmakers, mostly in Switzerland, began installing small spring-powered musical movements in watches, snuff boxes and other baubles. The bells that were the principal sound

component in the earliest objects were relatively bulky; it was to afford greater miniaturization that combs of tuned steel teeth were developed as the basic musical element."

The oldest music boxes have their tunes inscribed on metal cylinders. In the late 19th century, cylinders were superseded by metal disks, which could be stamped out by machine and were, thus, less expensive to produce. Ritz' collection contains both kinds of boxes, as well as orchestrions and carousel organs.

The international look of the collection is a result of the many overseas trips Henry Ritz has made with Roslyn, his wife of 58 years and daughter of Jessie Morton Schorr '16. The couple have three children and five grandchildren. "Every place we went, I would buy a music box representing the country we visited.

"A lot of people ask me: 'What do you think it is worth?'" Ritz says about the collection. "That answer is: 'What is it worth to you?' It may be worth $20 to you and $100 to me. Take the antique box. I wouldn't sell that for several thousand dollars. Now, whether anybody would pay that much is problematical."

In fact, the antique box is one of Ritz's favorites. He keeps it upstairs in the living room along with a few other choice pieces. He found it, not in Europe, but in a secondhand store in Worcester. Made sometime around 1890, it plays six different French tunes. A hand-written label still clearly lists each piece. When Ritz found this rare mechanical music box it was sorely in need of repair. He fixed it himself.

"I used to take them apart and put them together again," Ritz says. "They always needed fixing and lubricating. I was able to do that."

Ritz is no longer able to work on his beloved music boxes. Having suffered strokes in 1981 and 1988, he must use a wheelchair to get around. Still, he remains active and his spirit is undiminished.

"You are looking at an inspiration," Roslyn says, placing her hand on her husband's shoulder. "Even though it is 10 years now since he had his second stroke, he tries everything he can to live a normal life. He advises others who have had a stroke. He will write a letter to someone and tell them not to lose faith, to keep on trying as hard as they can, to do their therapy, help themselves, so that they can live a productive life."

Living a productive life is something Henry Ritz has always tried to do. Born in Worcester in 1916, the son of Samuel and Minnie Ritz, he graduated from Worcester's Classical High School in 1934 and the following year enrolled as an electrical engineering major at WPI.

"I lost my father in my senior year and I had to quit school," he says. It was a time when R&R's annual sales were, as Ritz puts it, "equal to what we do in two days now." For five years, he worked at R&R during the day and took courses at night at a satellite campus of Northeastern University in Worcester, earning a degree in business and engineering.

Started in 1905, R&R took its name from its founders, Samuel Ritz and Joseph Rutman, father of Walter Rutman '30. The company started out on Water Street and moved to Mechanic Street in 1929. In 1950, it moved to Worcester Center Boulevard, where its brightly colored neon sign, with its dripping faucet, become a local landmark. Three years ago, the site was taken by the city to make way for the massive Medical Center project now under construction in downtown Worcester. Since then, R&R has called Chandler Street home.

In 1987, at the age of 71, Henry Ritz turned the company over to his son Jesse. "Jesse's doing very well," he says. "I'm very proud of him. He was just selected president of the Jewish Community Center in Worcester."

Ritz says he also plans on turning the music box collection over to Jesse. "He has the room for it," he says. "You have to have a lot of wall space to show all those music boxes. He is the only one of the three children who has the proper space."

After nearly a half-century of amassing his collection and enjoying countless hours with his music boxes, Ritz is now a collector who wishes only to give and not receive. "I have no place to put them," he says, laughing. "I give them as gifts to grandchildren for birthdays. I would buy surplus ones and give them out as gifts: keychains, cigarette lighters, dolls, animals...."

The more than 150 music boxes in the collection of Henry Ritz '38 include some rare and unusual specimens. A box made to look like a box of Ritz Crackers plays "Puttin' on the Ritz." The antique box in the lower photo is among Ritz's favorites.

It's obvious how much pleasure Ritz finds in sharing the joys of music boxes. "I can't tell you how pleased Ray Morin was when I gave him a cigarette lighter that played his theme song," Ritz said, referring to the late dean of Worcester music critics whose music box played, "Für Elise" by Beethoven.

Through the years Ritz has given many lectures about his music boxes. He's spoken to many Worcester social groups and on occasion has placed his collection on display at the Worcester Public Library and similar venues. In his talks he would often note how the royalty of Europe took great pride in their music boxes. It was a form of appreciation to give each other such enchanting gifts. In his own way, Henry Ritz has continued this grand tradition of giving gifts for the generations.

—Williamson is a freelance writer and musician living in Worcester.

Sharing the Secrets of the Universe

BY JOAN KILLOUGH-MILLER

Imagine a classroom powered entirely by enthusiasm, and you'll get the general idea of the Solar Energy Education Center at St. Mary Central High School in Neenah, Wis. If the love of learning is a form of energy, then teacher and Solar Center Director Allan Clarke '77 is the source. His excitement is captured by his students, who transmit it through the school and out into the larger community.

"I love the way kids come into a classroom so expectant, and they absolutely energize you," he says. "It may sound corny, but it's so real. It's like—Wow! For 45 minutes, you can share with them some of the secrets of the universe!"

Words like "wow" and "whoa" and "awesome" crop up a lot when Clarke talks about the Solar Center, which broke ground in January and was dedicated in May. Housed in a converted storage garage on school grounds, the center boasts a 1,000-watt photovoltaic system, a 900-watt wind turbine, and solar energy demonstration equipment that would be the envy of many colleges. The center is home base to St. Mary Central's "Solar Team," keepers of two beautiful electric vehicles—a bright red dune buggy called the Solar Spirit and an electric-blue go-cart called Zephyr Lightning.

RICK EVANS

Teacher Allan Clarke with the Solar Spirit at the Solar Energy Education Center he directs at St. Mary Central High School in Neenah, Wis.

Clarke still can't get over the generosity and good fortune that brought the center into being. "The solar center is a visible manifestation of things I've always believed in and I've tried to do in the classroom," he says. "I don't know how I did it before. How could I possibly teach solar energy operating out of a filing cabinet in my classroom, where you can only have things out for a day, then you've got to put it all away?"

Inside the solar center, students can feel hot air blowing in from the solar heating panel, even on a Wisconsin winter day. They can pedal the "Energy Cycle"—a stationary bicycle that generates electricity—until they've made enough juice to light a light bulb or run a hair dryer. "When they see, for example, that it takes 100 hours of cycling just to heat up your bath water, they begin to value resources differently," says Clarke. "And when they connect it with burning natural gas, oil or coal, they start to understand that there's got to be a better way."

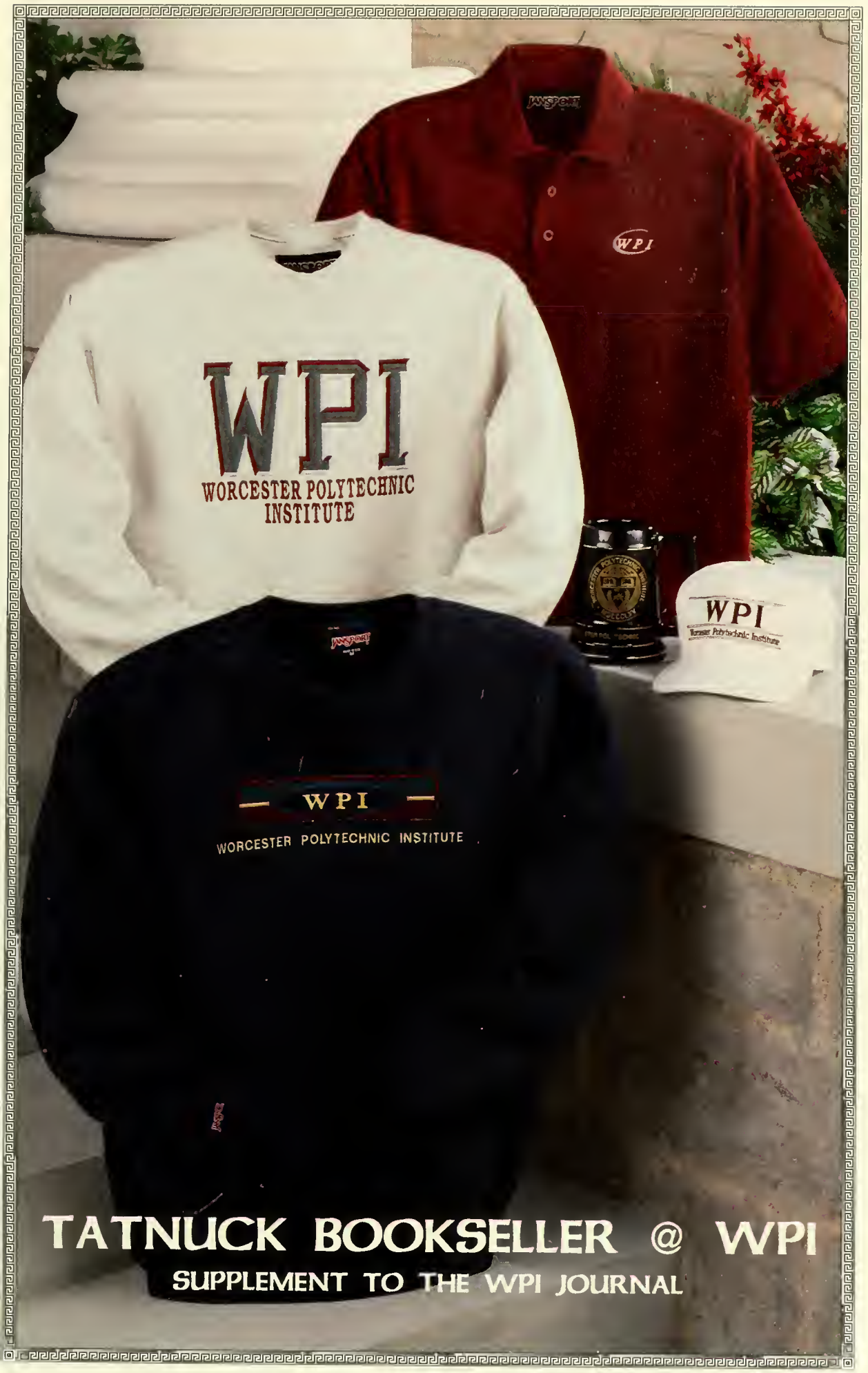
"There are so many ways you can teach energy," he continues, "from lighting a match, to bouncing a ball or shooting a rocket. I've always been a hands-on, involved teacher. I love deep theory, and I love to teach it. But it doesn't have to be heavy or dry. When kids can touch something that's real, it just sticks with them."

At community picnics and fairs, the Solar Spirit and the Zephyr Lightning draw a crowd faster than you can say "solar assisted vehicle." Kids are flabbergasted by a quiet engine that uses no gas and creates no fumes. The Zephyr Lightning, built by St. Mary Central students in 1994, impressed the local Community Foundation so much that it funded construction of the Solar Spirit, and later donated funds for a trailer so the cars could be displayed throughout the area. Enthusiasm and donations snowballed from there. In 1996, Clarke formed a partnership with the Fox Cities Children's Museum in nearby Appleton, and together they obtained a $20,000 grant for students to build a working photovoltaic exhibit for the museum.

As the solar team grew, Clarke dreamed of establishing a permanent home, where students could work on long-term projects, consult with professionals, and expand outreach to other schools and community groups. In the fall of 1997, Clarke learned that Wisconsin Electric Power Co. was offering a $15,000 photovoltaic system to the most deserving school or group in the state. With the deadline only weeks away, he and his wife, Ann, worked round the clock and pulled together a winning proposal.

A large local construction company, Miron Construction, volunteered its services for the $50,000 job of converting a storage garage to a solar education center. Other supporters rallied to the cause. The teamwork was documented in a video, which was shown at the dedication this spring.

Although Clarke is justifiably proud of the physical apparatus—the likes of which many college students never see—it's the humbling challenge of reaching young



ıg towns a chance to usc the solar center's ıcilitics. This fall he will bc teaching thc ·ate's first high school course on solar tcch-ology, and hc is excited about thc interest ·om educators from other parts of the ɔuntry, who seck guidance in starting alter-ative energy centers of their own.

With all thc plans and progress, Clarke ; still filled with wondcr over the simple henomenon that makes it possible for the ın to ereate clectricity through a flow of lectrons. "The science behind solar energy ; absolutely beautiful," he exclaims. His oice swells with joy as he compares the ıythmic motion of electrons to a symphony rchestra, or describes thc peaceful whirring f a wind turbine. This technology holds the ower to transform the world, says Clarke, ven beyond the invention of the wheel.

Three generations of the Clarke family re invested in the Solar Center and the ıture of alternative energy. Allan's father is .dward N. Clarke, a pioneer in the semi-ɔnductor field, who is professor emeritus of lectrical engineering, former associate dean f graduate studies and director of research, nd former head of the Center for Solar lectrification at WPI. A principal donor of ıe solar center, he was invited to speak at t. Mary Central's convocation and the ded-·ation of the center.

"It was exciting, as a father and also as ɔmeone interested in solar energy," he says. arah Clarke, Allan's daughter, is currently ne of the center's five co-directors. They ll agree that the best way to ensure the ıture of renewable energy is to put the eveloping technology into the hands of ɔung people.

Allan Clarke observes that kids may be ıore open to new technology than adults, ho are often locked into the status quo. ut when adults see the kids getting ex-ted, they tune in and start paying atten-on. Clarke thrives on these interactions, hen his students have the confidence to ıow visitors around the center and answer uestions.

"The kids become the teacher, and I just t back, loving all of this, because my role is ɔ get people teaching each other. That's hen I feel like my dreams have come true. It's just really, really, awesome. All because the sun can create electricity through a flow of electrons! You know, technology is a wonderful thing."

Allan Clarke's daughter Sarah, a co-director of the solar center, tries out the Zephyr Lightning, a solar-powered go-cart built by St. Mary Central students in 1994.

Sharing the

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Allan Clarke's daughter Sarah, a co-director of the solar center, tries out the Zephyr Lightning, a solar-powered go-cart built by St. Mary Central students in 1994.

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Sharing the

Imagine a classroom powered entirely by enthusiasm, and you'll get the general idea of the Solar Energy Education Center at St. Mary Central High School in Neenah, Wis. If the love of learning is a form of energy, then teacher and Solar Center Director Allan Clarke '77 is the source. His excitement is captured by his students, who transmit it through the school and out into the larger community.

"I love the way kids come into a classroom so expectant, and they absolutely energize you," he says. "It may sound corny, but it's so real. It's like—Wow! For 45 minutes, you can share with them some of the secrets of the universe!"

Words like "wow" and "whoa" and "awesome" crop up a lot when Clarke talks about the Solar Center, which broke ground in January and was dedicated in May. Housed in a converted storage garage on school grounds, the center boasts a 1,000-watt photovoltaic system, a 900-watt wind turbine, and solar energy demonstration equipment that would be the envy of many colleges. The center is home base to St. Mary Central's "Solar Team," keepers of two beautiful electric vehicles—a bright red dune buggy called the Solar Spirit and an electric-blue go-cart called Zephyr Lightning.

Clarke still can't get over the generosity and good fortune that brought the center into being. "The solar center is a visible manifestation of things I've always believed in and I've tried to do in the classroom," he says. "I don't know how I did it before. How could I possibly teach solar energy operating out of a filing cabinet in my classroom, where you can only have things out for a day, then you've got to put it all away?"

Inside the solar center, students can feel hot air blowing in from the solar heating panel, even on a Wisconsin winter day. They can pedal the "Energy Cycle"—a stationary bicycle that generates electricity—until that there's got to be a better way."

"There are so many ways you can teach energy," he continues, "from lighting a match, to bouncing a ball or shooting a rocket. I've always been a hands-on, involved teacher. I love deep theory, and I love to teach it. But it doesn't have to be heavy or dry. When kids can touch something that's real, it just sticks with them."

for the $50,000 job of converting a storage garage to a solar education center. Other supporters rallied to the cause. The teamwork was documented in a video, which was shown at the dedication this spring.

Although Clarke is justifiably proud of the physical apparatus—the likes of which many college students never see—it's the humbling challenge of reaching young

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minds that matters to him. "The Solar Center is really just a model for education," he says. "This center could have been devoted to robotics, it could have been for telecommunications...it just happened to be on the vital topic of energy. What I'm discovering is that most people have a deep thirst for knowledge. It's just a matter of how you turn that on and off."

In fact, it was at WPI that Clarke discovered his love of learning and his desire to teach. He was inspired by the "Comps"—Comprehensive Exams taken by seniors in the early years of the WPI Plan. To prepare for the exams, Clarke spent time with each of his professors, asking the questions that he never understood in class. He realized that he loved learning. But a number of his fellow seniors—some of whom had spent the winter break skiing or sleeping off the previous semester—had failed the exams and would not graduate. At Commencement, Clarke says he was filled with empathy, and a growing desire to go into teaching.

After a few years in research and development with Procter & Gamble and the former American Can Co., he earned his teaching certificate in high school science and mathematics at Lawrence University in Appleton in 1982 and accepted a position at St. Mary Central that summer. "WPI prepared me for teaching very well," he says. "It trained me not to just fill a slot but to create new opportunities. If there are needs, don't complain—fill them. If you see problems, fix them."

At St. Mary Central, students are beginning to consider it cool to be part of the Solar Team. Being elected a co-director is even cooler. "We're working hard at making it an awesome thing," says Clarke, "and what we're seeing is a new breed of leadership." He has some choice words to describe the type of students who manage the solar center: respectful, cordial, quiet, mature, modest. The co-directors take on responsibility without being asked, and never miss a meeting without prior notice.

"But we never forget that they are high school students," he asserts. "We don't want to fast-track their lives." Not all of the students are interested in technology: there are roles for artists and writers, fund-raisers, and would-be entrepreneurs. "They don't realize they're getting leadership, management and research practice, along with a chance to develop their people skills," adds Clarke.

"There are so many ways you can teach energy, from lighting a match, to bouncing a ball or shooting a rocket. I've always been a hands-on, involved teacher."
—Allan Clarke '77

The solar team's next step will be to bring electric vehicle racing to Wisconsin, with the goal of holding an "electrathon" in the year 2000. Clarke envisions having the electrathon vehicles lead the runners in the Fox Cities Marathon. He would also like to start an Explorers scouting post devoted to energy, to give students from the surrounding towns a chance to use the solar center's facilities. This fall he will be teaching the state's first high school course on solar technology, and he is excited about the interest from educators from other parts of the country, who seek guidance in starting alternative energy centers of their own.

With all the plans and progress, Clarke is still filled with wonder over the simple phenomenon that makes it possible for the sun to create electricity through a flow of electrons. "The science behind solar energy is absolutely beautiful," he exclaims. His voice swells with joy as he compares the rhythmic motion of electrons to a symphony orchestra, or describes the peaceful whirring of a wind turbine. This technology holds the power to transform the world, says Clarke, even beyond the invention of the wheel.

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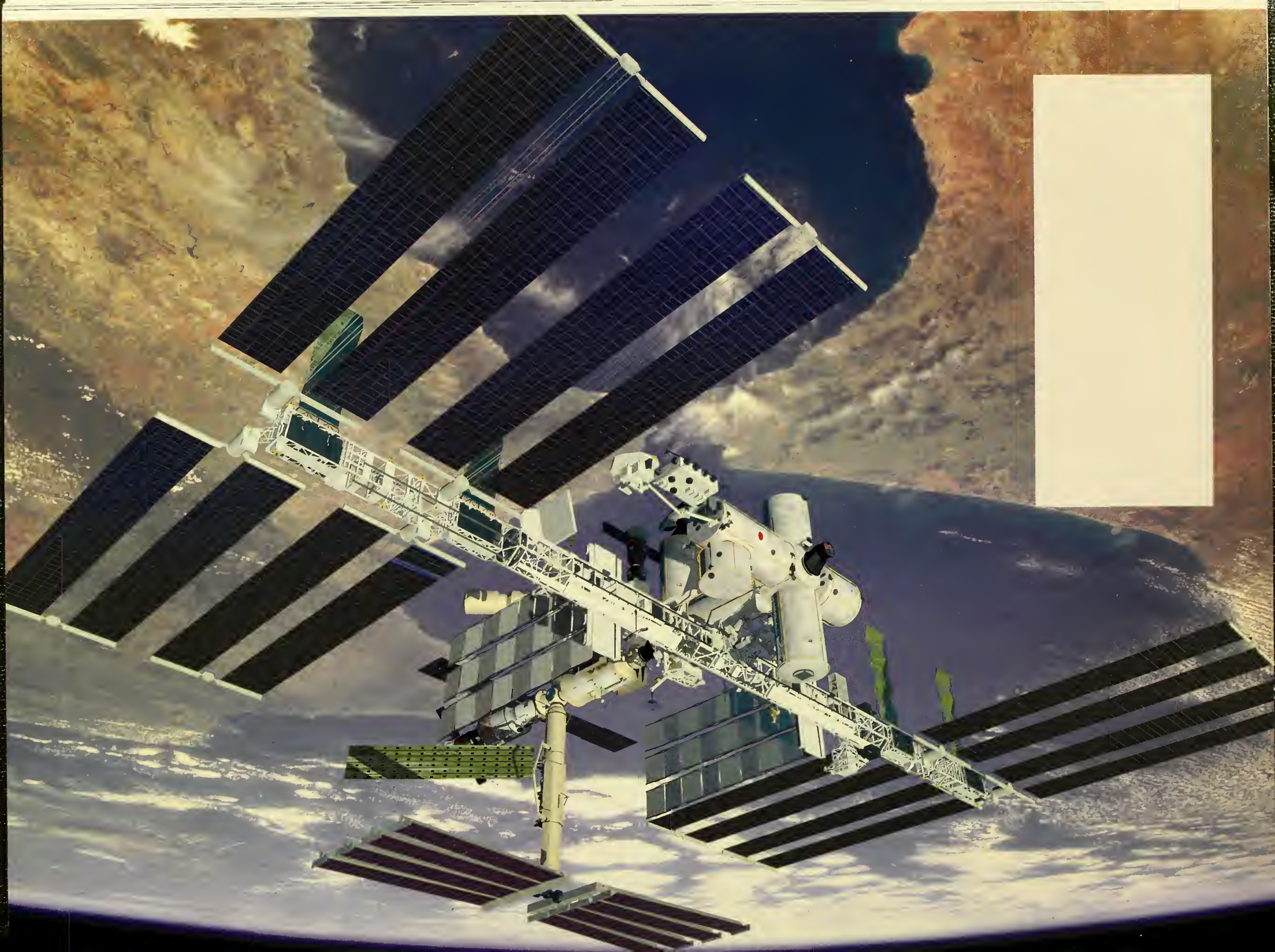
Allan Clarke's daughter Sarah, a co-director of the solar center, tries out the Zephyr Lightning, a solar-powered go-cart built by St. Mary Central students in 1994.



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WPI JOURNAL

WINTER 1999

A UNIVERSITY'S BEST FRIEND

The everyday life of campus computing

Editor's Note

They delight, amuse, enlighten and frustrate. They will follow our commands, but sometimes leave us shaking our heads or our fists. They are patient and faithful servants who thrive with just a little care and attention, but who can occasionally catch a virus or two. And though we might swear that things were easier before we had them, we know our lives would not be as rich or rewarding without them.

Perhaps it's not surprising that the same descriptions can apply to dogs and computers, for like canines, computers seem programmed to make us happy. Across the WPI campus, hundreds of computing machines hum eagerly, waiting to answer their owners' beck and call. Their owners have taught them some remarkable tricks. On the pages that follow, you will get a computer's-eye view of how Information Age technology has transformed life and work on our campus.

5:51 a.m. Ready when you are!

Ideas can spring up at any time, and before this one gets away in the heat of early morning business, Bradley Hosmer '61, a consultant in Concord, N.H., fires off an e-mail message to his alma mater. Modern computer tools have changed our perception of time and geography, and forever altered the way we live and work.

THE INDISPENSABLE TOOL

By Edward Alton Parrish

With the ubiquity of the Internet today, it's easy to forget how brief the life of this remarkable network of networks has been, or how explosively it's grown. In just three decades, the Net has evolved from an experimental network with four mainframe computers to a global spider's web of networks and backbones that links some 20 million host computers and more than 140 million individual users in 150 nations (according to one reliable estimate).

The Net's evolution from curiosity to essential tool mirrors the remarkable rise in the importance of computers and networks in the daily life of WPI. In 1969, when the Internet began (and when the WPI Plan was conceived), WPI owned just a few computers. The largest was in the new Worcester Area College Computation Center (WACCC), which ran programs for WPI and a number of area colleges. The first personal computers arrived on campus in the late 1970s, and by 1988 there were 800 in offices and general access labs.

In 1988, WPI built a high-speed campus network, giving most faculty members and administrators access to each other and to the Internet. Since then, things have been growing at a feverish pace. Today, computers and networks are indispensable elements of work and life at WPI, as you will see in the stories on the following pages. They play critical and growing roles in teaching and learning and are vital tools for our administration. By making possible instant, low-cost global communication and giving users access to a vast universe of information, they have transformed the way business gets done on our campus—usually for the better.

Not surprisingly, the University has invested heavily in its information infrastructure and in tools that make it easier to work, communicate, teach, do research and serve students. Just last year WPI spent over $1 million on improvements to the campus computer system, primarily to increase the speed of network connections in our residence halls and to build wireless links to our fraternity and sorority houses.

These investments have made WPI one of the most technologically sophisticated universities in the country. Last year, *Yahoo! Internet Life* magazine named WPI the No. 10 "most wired" campus in America. The magazine, in conjunction with college guide publisher Peterson's, surveyed more than 400 highly selective colleges and universities to identify those that provided students the greatest access to and benefit from leading-edge computer technology.

WPI's "wired" status should increase still further now that the University has been chosen to be part of an elite group of institutions that will design and test the next generation Internet. The Internet2 project will give WPI access to a network backbone capable of carrying information 1,000 times faster than today's Net. It will be interesting to see what mind-boggling ideas our faculty and students come up with for using all that bandwidth. As Al Jolsen might have said, you ain't seen nothin' yet, folks.

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Front cover photo and photos for this story by Patrick J. O'Connor; concept by Michael J. Sherman.

HOT-WIRING A FRESHMAN CLASS

These days, every college asks prospective students for e-mail addresses. WPI actually does something with them—making the University a leader in the creative use of technology in admissions.

About 45 percent of students who inquire about WPI use e-mail. For them, the Admissions Office plots direct mail and e-mail strategies. "We can target e-mail messages by a number of factors," says Monica Inzer, director of admissions. "These include ZIP code, gender, major, and how the student discovered WPI."

By using such segmented data, the Admissions Office can direct messages about last weekend's football game to, for example, all men from Wisconsin interested in football and physics. If a faculty member in biology and biotechnology will be lecturing in Omaha, admissions counselors can alert prospects interested in biology who live within that particular ZIP code. WPI student volunteers also reach out with messages about their majors and activities.

When a prospective student e-mails WPI a question or comment, an admissions counselor responds within 24 hours. That policy often means answering 70 to 80 messages per day (up to 200 when an application deadline looms), but the hard work pays off, Inzer says.

The personal communication that e-mail makes possible often generates responses from students who give WPI another look because of the electronic attention they've received. It is also part of the reason that applications to the University reached record numbers during each of the past two years, Inzer says.

And then there's the Web. WPI's Web site has an extensive admissions section that guides visitors through a variety of topics. Updated last summer, it continues to get good reviews. "We encourage kids to check us out on the Web," says Kevin Kelly, associate vice president for enrollment management. "It's available around-the-clock, so they can find information whenever they want it."

As 58 percent of all applicants discovered last year, the WPI Web site is also a good way to save $60. The Admissions Office, which was one of the first in the nation to put its entire application on the Web, waives the application fee for those who apply online. Inzer is quick to emphasize that "we don't favor Web applications over those that arrive in the mail." Still, Kelly adds, since Web applications go directly into the admissions database, "they save us a boatload of keystrokes."

The Admissions Office hasn't given up on "back to basics" admissions work. Admissions counselors visit high schools, invite guidance counselors to campus, attend college fairs, and host open houses. Since most high schools don't have e-mail yet, staff members have found there's still no substitute for face-to-face contact.

"But it's clear there's no going back," says Kelly. "Electronic communication enables many thousands of people to be out there representing WPI, instead of only six of us. It's a neat way to build relationships."

—Allison Chisolm

THERE'S NO "QUEUE" IN REGISTRATION

Registering for classes at WPI used to mean conga lines of students moving one, two or three steps at a time toward the harried staffers seated at desks in Harrington Auditorium. But thanks to the Internet, that dance is over.

Web-based registration has been available since the fall of 1997, when it was first offered to undergraduates. It was extended to graduate students the following year. By typing in a personal identification number and selecting from a menu of choices, a WPI student can sign up for classes, drop or add courses, pay bills, or find out what graduation requirements remain unfulfilled. It all can be accomplished from anywhere in the world, 24 hours a day, seven days a week, 365 days a year. The switch also benefits faculty members and advisors who may post grades over the secure Web and who have instant access to class lists and wait lists.

"We are one of a very few colleges to offer full Web-based registration," says Registrar Nikki Andrews. "It's incredible from the students' perspective. They love it."

Andrews says the system is particularly effective and appropriate at WPI because the University's flexible guidelines for majors enables students to tailor their courses to their interests and career goals. With a few moves of the mouse, they can find out which courses are open or get on a waiting list for ones that are filled. "I can register in my pajamas," wrote one happy undergrad.

The implementation of Web registration represents the first phase of WPI's reengineering initiative, which was launched in 1996 to find ways to better serve students, parents, faculty and alumni. "In the past, a student would submit his course requirements and receive his schedule in

three to four months," says Kari Blinn, the former WPI registrar who now serves as reengineering coordinator. "Now that process takes three to four minutes." The time it takes for a student to receive his final grades is equally remarkable. "We went from five days to five hours," says Blinn.

Andrews says doing away with the tension and tedium once associated with registration has reduced stress among her employees, who used to be gearing up or winding down from the hectic days at Harrington every seven weeks. Now, she says, they can give more time to people who come into the office for help or contact them via e-mail. "Everyone is smiling a lot more these days and student satisfaction is at an all-time high."

—Bonnie Gelbwasser

8:00 a.m. \ Here's your mail.

Overnight, dozens of messages from prospective students have piled up in Associate Admissions Director Mike Smith's e-mail box. That's but a drop in the bucket compared to what will flash through the WPI network today. By day's end, some 33,000 messages (1.7 gigabytes of information)—about one message every two and a half seconds—will flow through the e-mail server.

CLASSROOMS AT YOU

Learn to manage a company. Develop fire safety plans. Operate information technology systems. Engineer a healthier environment. The best part is, these days you can study these and other disciplines at WPI no matter where in the world you are. The University has embraced distance learning as a natural outgrowth of its excellence in technology. The idea that education doesn't have to take place in a building is as old as Socrates. But with the Internet's capacity to carry text, pictures, video and sound, the entire world has become a virtual lecture hall.

WPI's Center for Firesafety Studies was among the first academic programs of its kind to offer for-credit courses via distance learning. "We offer 21 courses to distance learning students at more than 50 sites in the United States and Canada," says Jonathan Barnett, associate professor of fire protection engineering. "And we have students in Australia and Sweden. At some point, one of our Australian students plans to come to campus to do his thesis. He wants to experience WPI's extraordinary labs and facilities." In the meantime, distance learning saves him an awesome commute.

PictureTel, a teleconferencing system that allows live interaction, and videotapes enable WPI to offer distance learning for all needs. Students and faculty can also use interactive Internet programs to hold electronic conversations in real time.

Karen A. Lemone, associate professor of computer science, has developed programs that fellow professors may use to enhance courses offered over the Web. Such courses, she says, are popular with students who grew up in the Computer Age. Productivity should improve for both instructors and students with features such as "retargeting" and automatic grading. "Retargeting tools enable instructors to create the next version of a class in far less time," Lemone says.

Judith E. Miller, director of WPI's Center for Educational Development, says distance learning may be the great equalizer in education. "Distance learning makes college courses available to people who, for whatever reason, cannot come to campus and take courses during the day."

The lack of human interaction can be a problem with distance learning. Does the fact that you may never meet face-to-face with your

THE LATTER-DAY CHALKBOARD

The first thing I did to research this story was to send someone an e-mail message. That's an act repeated thousands of times every day at WPI, where electronic technology has become a basic building block for professors and students. Course syllabi, homework, reading lists and more are posted on the WPI Web site. Students can access information day or night.

Michael A. Gennert, associate professor of computer science, admits he can't live without technology for library research, for staying in touch with students, parents and fellow researchers, and for managing classes. "I always put my courses on the Web," Gennert says. "The only papers I exchange with my class are a first-day handout and exams. Everything else is electronic."

Electronic learning also tends to be more experiential, providing real-world knowledge. "Traditionally, information is already digested for students," says Judith E. Miller, director of WPI's Center for Educational Development. "They don't have the opportunity to take primary information from the field and make it their own."

Technology changes all that. Students search out primary data and process large amounts. "Technology excels at visualization in a way that static media like textbooks and transparencies can't even begin to match," Miller says. In one class she teaches, students use visualization software to view rotating, three-dimensional models of molecules. This technique allows a more authentic education based on experience. "It's the difference between surface learning and deep learning," Miller says. "Students take information and process and draw inferences from it. The ability to do that is the hallmark of a truly educated person."

A networked campus improves communication between faculty and students, too. At WPI, even the stage wouldn't be the same without the e-mail connection. Susan Vick, professor of drama/theatre, who directed *Saint Joan* this fall at WPI, doubts she could have pulled off this major production without e-mail. "We notify people about rehearsals, jobs to be done—we even post schedules on the Web," she says. "We use it as a communication device to remind actors, designers and technicians of our artistic visions. We save rehearsal time for rehearsing."

History Professor John F. Zeugner finds that the objective, detached aspect of electronic communication actually frees students to ask more questions. "E-mail has dramatically increased my accessibility to students and their accessibility to me," he says. "I frequently learn things from e-mail that students are too embarrassed to ask or refer to in a classroom setting."

—Arlie Corday

FINGERTIPS

professor affect how you learn? "Part of it is communications style," answers Paul P. Mathisen, assistant professor of civil and environmental engineering. "As an experiment, we had two teams work on a proposed highway project. One met normally as a group; the other had no face-to-face contact. The distance-learning group did well; the other group had problems."

Whatever the teaching method, it seems some things never change. "The main thing is being able to work together," Mathisen says. "The only way these students can do this work well is to learn to work well as a team."

—Arlie Corday

11:13 a.m. | Teach me a new trick.

Chemical engineering Professor David DiBiasio reviews an online homework assignment with Matthew Dion '01 and Bonnie Henderson '01. Computers and networks have added a new dimension to education at WPI, improving communication between professor and student, turning the world into a classroom, and bolstering learning.

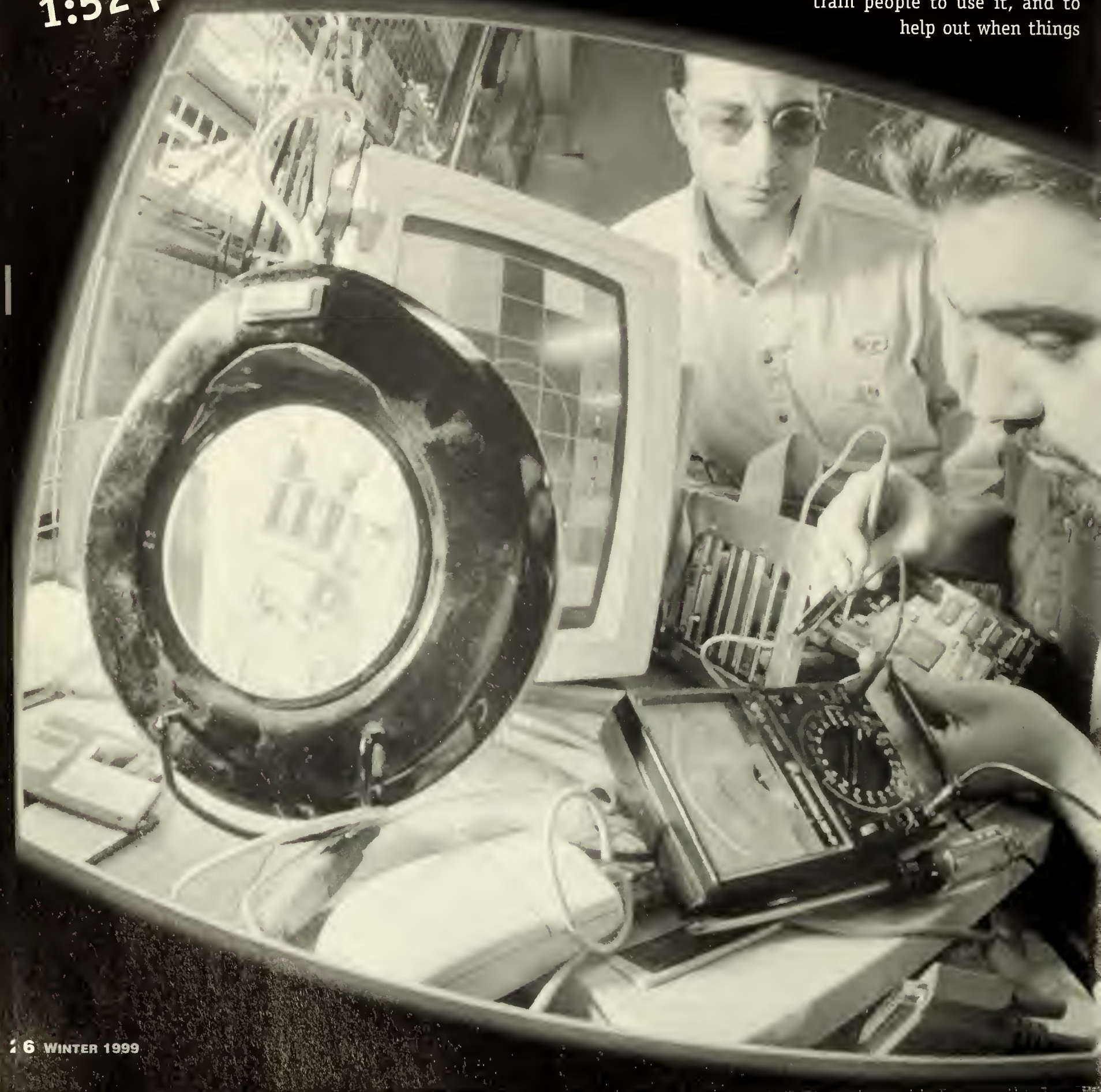
THE "I" TEAM

Scott Streeter, PC support/hardware technician, left, and Noah Abrahams, PC support technician, are part of a cadre of dedicated experts at WPI who keep thousands of computers and miles of network running, train people to get the most from their machines, and help out when users get in trouble.

1:52 p.m. | Is it a virus, Doc?

What does it take to become *Yahoo! Internet Life's* 10th most wired university in the nation? According to Tom Lynch, WPI's vice president for information technology, the ingredients include thousands of computers (mainframes, servers, workstations and PCs), hundreds of miles of copper and fiber-optic cable to connect them, and, of course, the latest and most useful software applications to turn them into state-of-the-art tools.

But even the most sophisticated information infrastructure would quickly grind to a halt, Lynch says, without a small army of dedicated men and women to maintain it, to train people to use it, and to help out when things



go awry. Those men and women work in the College Computer Center (CCC), under the command of CCC director Jim Jackson, managing senior UNIX systems administrator Al Johannesen and manager of administrative systems Ben Thompson.

Among the CCC's frontline operations is the Computer Shop, where PC support/hardware technician Scott Streeter, PC support technician Noah Abrahams and a staff of student workers maintain about 2,700 personal computers spread throughout labs and offices on campus. Like old-fashioned family doctors, they make frequent house calls to diagnose and fix problems, often hauling ailing machines back to the shop for surgery.

Keeping WPI's campus network running is the responsibility of network manager Sean O'Connor, who has been busy in recent months upgrading the network backbone to accommodate the constantly increasing demand placed upon it by users on and off campus. Having upgraded connections in every residence hall, O'Connor will soon begin a multiyear plan to replace networking equipment and wiring in every academic building with the fastest technology currently available.

When computers misbehave, the calls go to the Help Desk, WPI's in-house technical support line. Help Desk supervisor Marie DiRuzza, office operations support specialist Kerrie O'Connor, and a staff of more than 15 trained students answer the phones 10 hours a day on weekdays. "The Help Desk started as a student-run effort, but is today a professional service that receives hundreds of calls and e-mails every week—sometimes several hundred a day," DiRuzza says.

She says the nature of the questions she receives indicate that computer users on campus are becoming an increasingly sophisticated lot. That is due, in part, to the efforts of Debbie Babineau, WPI's computer trainer. Babineau offers a wide variety of scheduled classes and workshops on operating systems, e-mail programs, and a host of commonly used software applications. She teaches about 25 sessions in a typical two-month cycle, and offers custom designed training for departments.

In addition to meeting the needs of a constantly growing population of computer users on campus and at two branch campuses, the CCC staff must keep up with the continually accelerating pace of technological change, which requires frequent hardware and software upgrades and puts pressure on the computer staff to keep updating and expanding their areas of expertise. "Keeping up with technology," Lynch says, "can be a full-time job all by itself."

—Michael Dorsey

50% AND GROWING

When Alumni Affairs Director Tina Gorski-Strong '84 checks her mail, she's more likely to turn on her computer than open an envelope. Her experience parallels those of a growing number of WPI alumni—fully half of whom graduated during the last two decades. "I rarely get personal correspondence through the postal service," she says. "Alumni are more likely to pick up the phone or use e-mail."

The immediacy of e-mail opens up communication, she says. "It's an easy way for someone to quickly send news—good and bad. And it's meant greater communication with far-flung alumni around the globe. E-mail is an exciting tool we can use to let alumni know we haven't forgotten about them."

Gorski-Strong estimates that about 25 percent of alumni have e-mail accounts and that about 50 percent have access to e-mail in some fashion. "As a university, we're reaching out in different ways to alumni in different parts of the country and the world," she says. "Technology shrinks these distances. Of course, we'll continue to go out and visit alumni in person, but e-mail helps them feel connected to us between visits."

While Gorski-Strong uses e-mail primarily to respond to alumni questions, she has on several occasions "broadcast" time-sensitive news to all alums whose e-mail addresses are in the alumni database. This year, for example, when WPI wanted alumni to help prioritize the goals and initiatives in the report of the Planning and Implementation Committee, a message was broadcast to 4,600 graduates.

The centerpiece of electronic communications with WPI alumni is the Alumni Gateway, launched in the spring of 1996. Some 4,800 alumni have used their free accounts to check the alumni database prior to job interviews or sales calls; set up e-mail forwarding addresses; created special e-mail lists for their classes; or made a link to their own World Wide Web home page.

In alumni relations, the future looks more electronic every day. Already, Gorski-Strong says, she spends at least 25 percent of her day at the computer. She may spend even more time there in the future, as the WPI Alumni Association, grappling with ways to keep alumni involved with the University, hopes to increase its electronic outreach. One idea being considered is holding events for regional alumni groups that other grads can "attend" online.

But this new trend does not mean the end of the days of letters, direct mail campaigns and alumni magazines. "I'm acutely aware that not all alumni are connected," she says. "For the foreseeable future, we won't be switching completely to these new ways to reach out. But they do make excellent supplements to what we already do."

—Allison Chisolm

6:44 p.m. | Let's play fetch.

Gordon Library's computers are tireless retrievers, always ready to comb WPI's catalog, the Internet, and other electronic resources for books, journals, facts and figures users need. They're not always discriminating, but with experienced librarians helping point the way, computers have become indispensable adjuncts to this research library's extensive holdings.

WIDE LIBRARY

Computers are nothing new at WPI's Gordon Library. The staff has been working with them since 1974, when the library was connected to the Online Computer Library Center database of book holdings for libraries worldwide. "Our first electronically distributed information was the catalog, which we made available over the campus network in 1989," says library director Helen Shuster.

"The Internet, the campus network, the computer and, more recently, the World Wide Web, have transformed the role of the library. In the last four years alone, this technology has enabled us to provide far more information to our users via connections to more and more electronic databases and full-text periodicals. While this has increased our workload, we are now able to provide a much greater depth and breadth of information.

"There's a mass of information on the World Wide Web—some trivial, some vitally important," Shuster adds. "The library's role is to evaluate these resources and provide access to those who support WPI's academic mission. In addition, we focus on information literacy—helping patrons learn more about which resources to look for, where to find them, and what to do with them." Christopher Cox, who recently was hired to fill the new position of reference/instruction librarian, is helping expand information literacy to more WPI students and employees.

"So much information is available because of the network infrastructure we have in place at WPI," says Donald Richardson, reference/systems librarian. "Our catalog is online, accessible from anywhere, and we are able to offer access to sophisticated computer resources and support."

The challenges of acquiring and organizing electronic information requires every member of today's library staff to develop new skills and constantly upgrade them. Although they still have a library's responsibility for acquiring, organizing, archiving and ensuring access to information, technology continues to change not only the way they do these jobs, but the jobs themselves.

Here's a sample of what's happening at Gordon Library these days:

- Library staff are testing the latest release of Endeavor Voyager, the Web-based information system the library uses. "Gordon Library was chosen to be a test site because of our competent and knowledgeable staff," Shuster says.
- Librarians are actively involved with faculty in a program to investigate electronic submission of theses and dissertations and provide access to them on the Web.
- Electronic resources are constantly being added to the online catalog. Selected current links include the INSPEC bibliographic database for physics, electrical engineering, communications, and computer and information science; the FirstSearch suite of over 40 databases in multiple subject areas; Beilstein, the database of management and business information; and more than 500 full-text periodicals.

While electronic services are constantly being added, "this will not become a 'paperless' library anytime soon," Richardson says. "To a large extent, our patrons still need and use books. People still come here to read and study and work in project groups." In fact, last year the library's main door was entered nearly 215,500 times, 1,831 reserve items were checked out more than 14,550 times, and the Interlibrary Loan office handled over 7,000 requests for books and journals from other libraries.

When it was built in 1967, Gordon Library was designed to hold 200,000 volumes; the collection is now at 260,000. It is projected that the library shelves, as well as the auxiliary storage areas in Founders Hall, will be filled to capacity by 2001.

Shuster notes that the Planning and Implementation Committee (PIC) recently identified support for Gordon Library as an important future goal for the University. At PIC's request, Shuster drafted a library initiative that calls for an endowment that will help offset the increasing costs of print and electronic resources and enable the University to redesign the building.

"We hope," she says, "that an improved building and additional resources will enable Gordon Library to provide the types of services required to support the needs of faculty and students well into the 21st century."

—Bonnie Gelbwasser

SiLiCON-BASED (SOCiAL) LiFE

Greg Snoddy paints a perfect picture of interaction in the Information Age. "Two roommates are playing chess," says Snoddy, director of orientation and student activities. "But there's no table, no board, no chess pieces, and no eye contact between the players. Instead, each is focused on a separate monitor, competing against the computer."

Snoddy knows the challenges of keeping students in touch as well as anyone; his office is the clearinghouse for about 135 WPI clubs and organizations. The mailboxes in the Student Activities Office aren't as full of notes and flyers now that everyone on campus has access to computers, he says. Almost everyone connected to WPI now uses e-mail to get the word out about meetings, elections, programs and events because it's easy, instantaneous and saves paper and time. By pressing a few keys, groups can set their calendars, work out budgets and elect officers. The system is so good that some groups never meet in person.

But communicating via computer isn't what student life is all about. Creating community is, and in-person interaction is still the best way to achieve that goal. The Student Life Office and its affiliated offices are where students arrange for housing, learn about extracurricular programs and activities, resolve conflicts, and address health issues. These days, however, much of what used to be done in person during school hours can now be accomplished any time, any day, often anonymously. And that's the challenge.

Janet Begin Richardson, associate vice president for student affairs and dean of student life, says it wasn't very long ago that she'd arrive at work to find a line of students waiting to talk to her. Today that line is more likely to form in her e-mail in box, where she says it's not unusual to find 35 messages some mornings. "It used to be that students knew they'd have to wait to talk to me in the morning or after the weekend," she says. With e-mail's instant access, Richardson is contacted more often by more students because they can write to her as soon as an issue comes up. "The downside is that I see fewer students in person these days and I miss getting to know them."

"Computers are replacing some human contact," she says. Fewer students head for the lounges in residence halls to converse or relax. Instead, more and more do their socializing online. "We now train our RAs to look for students who are isolating themselves in their rooms," says Richardson. "It's easy to close your door and click on the computer. There's so much out there. But it's especially important for college students to leave their desks and books at times and have fun, and we really focus on encouraging them to learn about and take advantage of the wide variety of opportunities for social interaction available on this campus."

Snoddy sees another side to the issue. "Our students are technologically literate," he says. "But that isn't enough to succeed in college or in life. What we strive to do is balance this competence with opportunities for social interaction. Students need to be able to feel comfortable in interpersonal relationships as well as on the Net to succeed as a member of the WPI community and in their careers."

Creating community is encouraged from the time new students arrive on campus. Since 1997 an innovative program has been a part of New Student Orientation. During NSO, the newcomers separate into heterogeneous teams of about 25 students to create a "virtual community." Working with an Orientation Leader and a faculty consultant, each team designs a Web site for a "virtual student" with a four-year schedule tailored to his or her major, personality, hobbies and interests. "The exercise has been a wonderful way for students to begin building relationships with each other and with the University," says Snoddy.

One of the newest and easiest ways to learn about programs and events and even meet people in the Colleges of Worcester Consortium and beyond is via the Social Web at www.socialweb.net. Troy Thompson '95, a graduate student in biomedical engineering who is operations supervisor for the College Computer Center, created and maintains the site, where you can find everything from bus schedules to conferences, concerts and community service opportunities. There's even a matchmaker section for people to get together for events, organizations to find new members, and individuals to meet compatible companions. This option-filled, user-friendly site enables individuals to tailor how they want informa-

tion transmitted and received and to identify themselves to others through hundreds of characteristics.

Computers will also be a vital part of the new Campus Center. "We have to project into the future and figure out what the patterns of use will be," says Richardson. "There will be computer drops throughout the building for PCs and laptops, and terminals so they can check their e-mail."

And tables for those who still want to play chess against real people!

—Bonnie Gelbwasser

10:31 p.m. | Finally, time for fun!

As Moses McCall '01 and Jessica Hamel '99 know, WPI's computer network is now the thread that holds together its social network. To make friends and find out what's happening on campus, students often turn to the computer. While they sometimes replace human contact, e-mail, the Web, chat programs and bulletin boards can also bring people together.

Making Plans, Expanding Horizons

An architect's rendering of the entrance to the WPI campus center as seen from Reunion Plaza.

Last year, long before the worldwide countdown to the new millennium ratcheted into full gear, WPI was already aggressively formulating a blueprint to position and strengthen the University for the 21st century. In 1997-98, the building blocks of plans and programs for the WPI of the future included

- the second phase in the creation of a new strategic plan,
- a program of strategic tuition and fee increases to provide resources to begin raising WPI's quality in advance of a major capital campaign,
- the receipt of two landmark gifts,
- strides toward construction of a campus center,
- expansion of the Global Perspective Program,
- honors garnered by a dedicated and talented faculty, including a Fulbright fellowship and five NSF CAREER awards.

"WPI is opening the door to the new century with visionary programs, an enhanced curriculum that is responsive to the needs of the global economy, and improvements and additions that benefit all who learn and work here," says President Edward Alton Parrish. "We're at the crossroads of our journey into 2001 and beyond —a voyage that will secure our position as a world leader in technological education."

What follows is a look at some of the milestones of 1997-98.

Strategic Planning Paves Road to Next Campaign

In the fall of 1997, the Planning and Implementation Committee (PIC) succeeded the Strategic Plan Steering Committee (SPSC), which had begun the process of developing a new strategic plan in 1996-97. During the year, PIC used SPSC recommendations and the reports of 13 task forces to formulate five goals and 21 strategic initiatives. These included adding to our full-time faculty while retaining the current size of our undergraduate student body, nurturing research and scholarship, enhancing library facilities and services, improving the first-year experience, and making the curriculum truly global. At the beginning of the current academic year, members of the WPI community were invited to prioritize these goals and initiatives, which Parrish is crafting into a final strategic plan to guide our future efforts.

In his State of the University address in March 1998, Parrish said WPI had begun a five-year plan of strategic tuition increases that will enable the University to make immediate investments designed to raise its quality. The program was prompted by a confluence of national studies and initiatives aimed at reforming technological education. These efforts are leading to a model quite similar to the one WPI developed 30 years ago, providing the University with a critical opportunity to gain increased recognition and prestige (see "Making Big Plans," *WPI Journal*, Summer 1998).

Revenue from the first year of the program helped WPI hire new faculty members in high-demand areas, renovate several classrooms and transform some into state-of-the-art multimedia facilities, and expand the Global Perspective Program—the most ambitious and successful program of its kind at any American technological university.

This April WPI will launch a major comprehensive campaign that will continue to build the University's quality and prestige by raising revenue to construct a campus center and to meet a host of other objectives. Two significant gifts received during the quiet phase of the campaign in 1997-98, $5 million from Worcester's George I. Alden Trust and $2.6 million from the estate of Harry A. Sorenson '30, will help meet two of the likely

goals of the eampaign: constructing a new academic building and providing endowed scholarships for undergraduate students.

The Alden grant equals the largest gift in WPI's history: the 1965 bequest from George C. Gordon, Class of 1895, whieh was used to build Gordon Library. The new grant will support the eonstruction of a 48,000-square-foot academic building that will feature technologically advanced classrooms and much-needed faeulty offices. The $13.1 million structure will rise from the hillside adjacent to the library and just below the Washburn Shops. The building is being designed to house the Department of Humanities and Arts, the Department of Management, and the Division of Continuing Studies.

The Sorenson bequest, the seeond largest gift in WPI history, will be used to establish a scholarship fund named for the donor. Originally from Hartford, Conn., Harry Sorenson was a seholarship student who majored in meehanical engineering at WPI and went on to earn a master's and a doetorate at the University of Michigan. He spent the first part of his career in industry, working for Stone & Webster, the Hartford Metropolitan District, and Pratt & Whitney Aircraft. In 1948 he joined the faeulty of Washington State University and was head of its Mechanieal Engineering Department for 20 years until his retirement in 1973. He and his wife, Merella, who died in 1991, were married for 60 years.

Action by the Board of Trustees in Oetober 1997 put the long-awaited eampus center on the eonstruction calendar. The trustees voted to break ground for the new crossroads of the eampus on or before Oct. 31, 1999, contingent upon having 90 percent of the estimated $17.2 million cost in place. Shepley Bulfinch Richardson and Abbott had been chosen earlier in the year to design the turreted, 71,000-square-foot strueture, which will be built parallel to Olin Hall on the upper Higgins House grounds.

Alumni Master Plan Takes Shape

New ideas and new plans were also the big stories for the WPI Alumni Assoeiation in 1997-98. The association's Exeeutive Committee and the Alumni Counеil approved a new five-year master plan for the association, which includes new vision and mission statements. The assoeiation also approved the reorganization of the Alumni Fund Board and its renaming as the Alumni Funds Board. The board provides adviee and guidance for WPI's Annual Giving Program.

At the end of the year, assoeiation President Robert E. Maynard Jr. '63 was looking forward to the reports of four task forces that are developing reeommendations and plans that build on four critical program areas identified in the new master plan. These are the organization of the Alumni Association's leadership bodies, eommunication with alumni, geographically targeted programming for alumni, and eareer development serviees and lifelong learning for alumni.

WPI Celebrates Its Expanding Global Reach

The Global Perspective Program drew a reeord number of undergraduates last year. More than 700 students attended the Global Opportunities Fair in September 1997; approximately 350 applied for off-eampus projects in the days following the event—double the number for the same period in 1996. As of May 1, 1998, more than 370 students had been aeeepted for off-campus Interaetive Qualifying Projeets or Major Qualifying Projects in 1998-99 in project sites in Washington, Boston, London, Bangkok, Darmstadt, Venice, Costa Rica, Puerto Rico, Denmark, Holland and Australia.

Natalie Mello, program administrator for the Interdisciplinary and Global Studies Division, attributes the explosion of interest in off-campus projects to the dedication and support of faeulty members and administrators and to the Global Ambassadors Program. Established in August 1997, the program harnesses the enthusiasm of Global Ambassadors (student veterans of off-campus projects) who get the word out about the exciting project opportunities available in other parts of the country and abroad. The ambassadors give presentations, maintain displays, and take part in admissions open houses and the global fair. Hossein Hakim, co-chair of the Interdisciplinary and Global Studies Division, lauds the faculty and administration for their support.

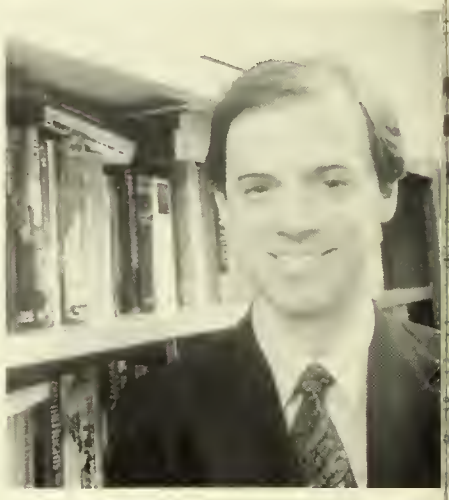
In A-Term, 12 students from four teams inaugurated WPI's first eenter established speeifieally for work on Major Qualifying Projects, loeated at NASA's Goddard Spaee Flight Center in Greenbelt, Md. "This site, a world-renowned research faeility for unmanned spaeeflight, was a natural choice for this initiative," says Fred J. Looft III, electrieal and eomputer engineering professor and program director. "NASA administrators are pleased with the high level of engineering expertise our students bring to the center's ongoing projeets." A WPI alumnus, H. Richard Freeman '61, is the chief engineer

Below, left, WPI's Global Ambassadors are veterans of off-campus projects who share their experiences and their enthusiasm for projects outside of the city and the country. Below, right, President Parrish enjoys a visit last spring with kindergarteners at a school sponsored by the Duang Prateep Foundation in the Klong Toey slum near WPI's Bangkok Project Center. Foundation Director Prateep Ungsogtham Hata is at left.

for Goddard's Engineering and Technology Directorate. WPI administrators continue to explore project and faculty-partnering opportunities at the center.

In March 1998, WPI celebrated the 25th anniversary of its programs in London with a gala at the U.S. Embassy hosted by President Parrish and The Honorable Philip Lader, America's Ambassador to the Court of St. James. Guests from around the world attended the event, which was followed by the inaugural meeting of the President's International Advisory Board. The PIAB, which consists of prominent alumni and other international executives and business leaders from the United States and several other nations, was established to help WPI expand its leadership role in global technological education.

Jessica Sands '98 had the starring role in *Medea*. WPI's version of the Greek tragedy featured cutting-edge technology that included virtual reality.



WPI professors, clockwise from top left, Heineman, Labonté, Hansen, Lurie, Hermanson, Paar and McNeill.

Honors Accumulate for Accomplished Faculty

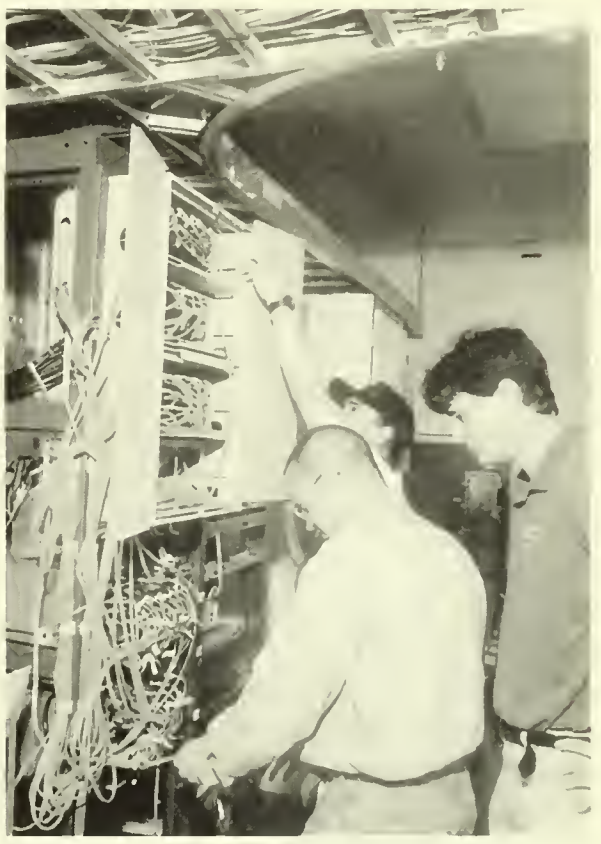
Five WPI professors were honored with National Science Foundation Faculty Early Career Development (CAREER) Program awards. The NSF program encourages young faculty members to develop as educators and researchers. Seven WPI faculty members have received CAREER awards since the program began in 1995.

The 1997-98 winners are **George T. Heineman,** assistant professor of computer science, **James C. Hermanson,** associate professor of mechanical engineering, **John A. McNeill,** assistant professor of electrical and computer engineering, **Christof Paar,** assistant professor of electrical and computer engineering, and **Fabio H. Ribeiro,** assistant professor of chemical engineering (June 1997). **Chrysanthe Demetry,** WPI's Norton Assistant Professor of Mechanical Engineering, and **Barbara E. Wyslouzil,** associate professor of chemical engineering, received CAREER awards in 1995.

Joshua P. Abrams, a master teacher of mathematics at the Massachusetts Academy of Mathematics and Science at Worcester, which is located on the WPI campus, received a Presidential Award for Excellence in Teaching from the National Science Foundation. Abrams was cited for his exceptional talent, leadership abilities and dedication. The award included a $7,500 grant to the academy.

Peter H. Hansen, associate professor of history, was elected a Fellow of the Royal Historical Society. Founded in 1868, the organization is the premier society in Great Britain for the promotion of the study of history. Historians may be elected to fellowship if they have made an original contribution to historical scholarship in the form of significant published work. Hansen, who directs WPI's interdisciplinary International Studies Program, is an expert on British history and Europe in the 20th century. He spent the summer of 1998 at the Australian National University's Humanities Research Center in Canberra, where he continued his research on the history of British mountaineering.

Electrical and Computer Engineering Professor **Robert C. Labonté** was named WPI's first Professor of Practice. This new type of faculty appointment was created in 1997 to attract proven leaders in industry and government to teach and share their expertise.



Above, the baseball team earned its first Constitution Athletic Conference title. The team finished its second consecutive winning season at 16–13—tying the school record. Above right, GM Executive Vice President Ronald Zarrella '71 gave the 1998 Commencement address. Right, the Greek Networking Project extended the campus network wirelessly to each fraternity and sorority house.

Konstantin A. Lurie, professor of mathematical sciences, received a Fulbright grant to do research and teach at the Technical University of Denmark in Lyngby. Lurie is planning to conduct research in spatio-temporal design at the university this spring.

New Programs Broaden WPI's Educational Horizons

In 1997-98, WPI became the first university in the world to offer a bachelor's degree program in system dynamics, a method of studying and modeling complex systems on the computer. The program, which requires course work in engineering, the social sciences, mathematics and computer science, was established in response to the need to understand and control socioeconomic systems. "Our graduates will be able to use system dynamics computer-simulation modeling to solve problems in a wide range of policy areas relevant to engineering, economic and societal systems," said Khalid Kaheed, head of the Social Science and Policy Studies Department. "WPI is leading the way into a new frontier," noted Jay W. Forrester, Germeshausen Professor Emeritus at MIT, a pioneer in system dynamics and the keynote speaker at a reception at which the new major was announced.

Civil and Environmental Engineering joined with four other departments to establish a new Management, Environmental, International (MEI) option within WPI's additional doctoral programs. A five-year, $562,000 grant from the National Science Foundation supports the program, which is designed to educate students in the management of technology, environmental responsibility, and problems associated with international competitiveness.

Last winter, WPI and the Escuela Superior Politecnica del Literal (ESPOL) in Guayaquil, Ecuador, signed an agreement to enable as many as 25 ESPOL students to come to WPI. Up to 15 will be allowed to complete their last two years of college here; 10 more could complete M.B.A.s or master of science degrees in operations and information technology or in marketing and technological innovation. The new partnership is the second for the two universities. In 1992 WPI was part of a five-year, $500,000 U.S. Agency for International Development program that promoted linkages between institutions of higher learning in the U.S. and developing countries. That program was extended in the fall of 1997.

Economics and Education Focus of Two Major Meetings

One of the year's highlights was the May meeting of the Industry/University/Government Roundtable on Enhancing Engineering Education. NASA Administrator Dan Goldin was the keynote speaker for the meeting—the first on a university campus. IUGREEE grew out of a series of Boeing Company roundtables at which industrial, academic and government leaders were encouraged to discuss issues and concerns about the future of the engineering profession and of engineering education. Last year's action teams reported on academic programs for the year 2010, enhancing the engineering profession, career-long learning mechanisms, and integrating information and computational advances. President Parrish is an IUGREEE member.

The economic summit "Manufacturing Our Future" drew 400 leaders of industry, academia and government to campus on Sept. 15, 1998. Paul S. Kennedy '67, president of Kennedy Die Casting in Worcester, chaired the event, which focused on how manufacturers in Worcester and the region will need to respond to market demands of the global economy to maximize their strengths and resources. All-Energy LLC and the (Worcester) *Telegram & Gazette* sponsored the all-day summit, which was organized by the Central Massachusetts Manufacturing Partnership, the Greater Worcester Chamber of Commerce and the Colleges of Worcester Consortium, in cooperation with U.S. Rep. James P. McGovern, D-Mass. WPI hosted a second summit in December 1998 that featured the announcement of the Central Massachusetts Regional Compact, in which key leaders, including President Parrish, pledged to work cooperatively toward the growth and renewal of the region's economic and environmental health.

—BONNIE GELBWASSER

FINANCIAL SUMMARY AND HIGHLIGHTS

By Stephen J. Hebert '66
Vice President for Administration, Treasurer and Secretary of the Corporation

On June 30, 1998, WPI completed another highly successful year, both operationally and financially. The University finished the year with an operating budget surplus of $464,000, which was subsequently reduced to $17,000 through three transfers to reserves.

Considerable good news during the year had a favorable effect on the financial picture. Perhaps the most important news concerned the financial aid budget, which for the first time in over a decade saw virtually no increase from the previous year. For the last several years, the percentage of freshmen receiving grant aid had stood at about 78 percent, with the average award increasing every year, sometimes in line with the increasing cost of attending WPI, and sometimes at a faster rate. In FY98, however, the percentage of freshmen receiving need-based grant aid declined to 73 percent, and the average grant declined, as well. The geometric impact of that decline had a positive impact on the FY98 operating budget, an effect we hope will continue in subsequent years.

The total amount WPI awarded in merit and need-based aid during FY98 was actually $225,000 less than it awarded the previous year. With this aid, WPI was able to secure a freshman class of 689—14 more students than it had budgeted for; while graduate enrollment was less than the budgeted number, the net effect of undergraduate and graduate enrollments was a positive variance from tuition revenue in a budget that is 63 percent-driven by net tuition.

Another bright spot during the year was the performance of WPI's continuing education operation. In its second year, the Waltham Campus continued to achieve outstanding results in terms of enrollment and net income. The Waltham operation and the balance of the University's continuing education programs produced a net contribution to the operating budget of $1.6 million.

As the value of the endowment has continued to increase in recent years, WPI has benefited from an increase in the funds available as a result of the endowment spending rule. The spending rule, which is set at 5.5 percent, is based on a two-year moving average of the endowment at the close of each fiscal year (albeit one year removed). In FY98, the contribution of the endowment to the operating budget increased by $600,000, to $5,276,000.

Overall, the balance sheet increased by $74 million during the year. Most of this increase was due to the continued positive impact of the equity markets. On June 30, 1998, WPI's endowment stood at $254 million, up 16.6 percent from the value at the close of the previous fiscal year. The two-year annualized rate of return was 19.7 percent, the three-year return, 19.3 percent, and the five-year return, 15.6 percent. While these returns are unprecedented and not likely to continue, they have produced a positive effect on the overall financial operation and condition of WPI.

During the year, there was continued excellent response to the early phases of a major capital campaign, which will be publicly launched during FY99. On June 30, total commitments to the campaign had reached approximately $40 million; the effect of some of the campaign gifts, as they relate to endowed funds, will begin to have an impact on the total operation of WPI in coming years.

Work continued during FY98 on the program and design for a campus center. The Board of Trustees has committed to breaking ground for the building no later than Oct. 31, 1999; it is anticipated that the center will be funded at the board-mandated level of at least 90 percent of the total project cost on or before that date. Fund-raising for the building through the capital campaign continued to make good progress during the year; in addition, a total of $5.6 million has been committed to the project from the bond issue completed late in FY97. Also during FY98, WPI received $5 million from the George I. Alden Trust that will be applied to the construction of a new academic building on campus. Shortly after the close of the fiscal year, architects were engaged to design the facility and a large parking structure that will expand available parking on campus, long a source of concern.

Standard and Poor's and Moody's continued to rate WPI A- and A2, respectively, in FY98, placing WPI in the upper ranks of American colleges and universities.

Years ended June 30, 1998 and 1997

1. General Operating Funds

(Thousands of Dollars)	1998	1997	Percent Change
Tuition, fees and other educational revenues	$61,915	$57,931	+6.9%
Student financial aid	19,518	18,610	+4.9
Gifts and bequests received	30,822	8,258	+373.2
Revenues from sponsored research programs	6,120	7,518	-18.6
Total staff benefit expenses, before allocation	7,817	7,502	+4.2

2. Endowment and Similar Funds

(Thousands of Dollars)	1998	1997	Percent Change
Beginning asset market values	$214,395	$177,406	+20.9
plus:			
Investment results			
Income (interest and dividends)	$4,640	$3,610	
Realized and unrealized gains	32,293	34,910	
Total investment results	$36,933	$38,520	-4.1
less:			
Used in support of college	(5,357)	(6,818)	-21.4
Net reinvested in endowment	31,576	31,702	-0.4
plus:			
Additions to endowments	8,475	5,287	+60.3
Ending asset market value	$254,446	$214,395	+18.7

Five-Year Summary of Total Return Data

	'98	'97	'96	'95	'94
WPI Total Return	16.6%	22.9%	18.5%	16.9%	4.0%
WPI Policy Index	17.1	20.7	16.9	18.5	3.2
S&P 500	30.3	34.9	26.1	26.1	1.4
LB G/C Bond Index	11.3	7.8	4.7	12.8	-1.5
CPI Index	1.8	2.9	2.8	3.1	2.5

Copies of the complete audited financial reports for WPI for Fiscal Year 1998 can be obtained by writing to:
WPI Office of Business Affairs
100 Institute Road
Worcester, MA 01609-2280

WPI

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FINANCIAL STATEMENTS

ANCIAL STATEMENTS OF THE UNIVERSITY FOR THE FISCAL YEAR 1998 • A SUPPLEMENT TO THE WPI JOURNAL

REPORT OF INDEPENDENT ACCOUNTANTS

The Board of Trustees
Worcester Polytechnic Institute:

In our opinion, the accompanying statements of financial position and the related statements of activities and of cash flows present fairly, in all material respects, the financial position of Worcester Polytechnic Institute at June 30, 1998 and 1997, and the changes in its net assets and its cash flows for the years then ended, in conformity with generally accepted accounting principles. These financial statements are the responsibility of the University's management; our responsibility is to express an opinion on these financial statements based on our audits. We conducted our audits of these statements in accordance with generally accepted auditing standards which require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements, assessing the accounting principles used and significant estimates made by management, and evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for the opinion expressed above.

PricewaterhouseCoopers LLP

September 30, 1998

Statements of Financial Position

June 30, 1998 and 1997

Assets	1998	1997
Cash and cash equivalents	$ 14,900,501	$ 14,473,586
Accounts receivable, net	4,123,173	3,665,575
Accrued income receivable	363,308	348,076
Contributions receivable, net	14,489,415	2,193,239
Inventories	11,461	12,256
Deposits with trustees	16,928,178	21,989,745
Prepaid expenses and other assets	902,308	995,349
Notes receivable	15,562,432	14,692,079
Intermediate and long-term investments	264,105,175	221,046,818
Land, buildings and equipment, net	65,456,617	63,750,281
Total assets	**$ 396,842,568**	**$ 343,167,004**

Liabilities and Net Assets		
Accounts payable and accrued liabilities	$ 7,481,244	$ 6,838,137
Deposits and deferred revenues	2,723,943	2,926,937
Short-term portion of long-term debt	1,625,936	1,695,200
Annuities payable	2,564,410	2,058,419
Funds held for others	407,961	329,210
Refundable government loan funds	9,163,434	8,982,466
Long-term debt, net	63,096,294	64,687,592
Total liabilities	**87,063,222**	**87,517,961**
Net assets:		
Unrestricted	165,238,462	147,793,560
Temporarily restricted	84,681,327	57,017,940
Permanently restricted	59,859,557	50,837,543
Total net assets	**309,779,346**	**255,649,043**
Total liabilities and net assets	**$ 396,842,568**	**$ 343,167,004**

Statement of Activities

for the year ended June 30,1998

	Unrestricted	Temporarily Restricted	Permanently Restricted	Total
Operating revenues:				
Tuition and fees	$ 51,678,814	$ –	$ –	$ 51,678,814
Less: unrestricted student aid	14,559,841	–	–	14,559,841
Endowed scholarships	2,137,399	–	–	2,137,399
Externally funded student aid	2,820,734	–	–	2,820,734
Total student aid	**19,517,974**	**–**	**–**	**19,517,974**
Net tuition and fees	32,160,840	–	–	32,160,840
Other educational operations	10,236,619	–	–	10,236,619
Contributions	7,172,377	885,493	–	8,057,870
Contract and exchange transactions	10,438,242	–	–	10,438,242
Investment income on endowment	4,572,678	2,854	65,254	4,640,786
Net realized and unrealized gains on endowment, expended	2,188,532	1,696,287	58,086	3,942,905
Other investment income	2,756,015	94,026	39,595	2,889,636
Gain on sale of real estate	23,500	–	–	23,500
Sales and services of auxiliary enterprises	8,147,451	–	–	8,147,451
Other	764,944	–	–	764,944
Total revenues	**78,461,198**	**2,678,660**	**162,935**	**81,302,793**
Net assets released from restriction	2,727,614	(2,727,614)	–	–
Total revenues and other support	**81,188,812**	**(48,954)**	**162,935**	**81,302,793**
Operating expenses:				
Instruction and department research	35,369,264	–	–	35,369,264
Sponsored research	6,118,902	–	–	6,118,902
External relations	3,118,888	–	–	3,118,888
Institution and academic support	11,550,125	–	–	11,550,125
Student services	4,896,779	–	–	4,896,779
Operation and maintenance of plant	12,808,790	–	–	12,808,790
Auxilliary enterprises	6,125,706	–	–	6,125,706
Total operating expenses	**79,988,454**	**–**	**–**	**79,988,454**
Change in net assets from operating activities	1,200,358	(48,954)	162,935	1,314,339
Nonoperating:				
Realized and unrealized gains	16,113,570	13,629,584	285,612	30,028,766
Change in value of split interest agreements	12,460	10,169		22,629
Contributions	118,514	14,072,588	8,573,467	22,764,569
Change in net assets from nonoperating activities	16,244,544	27,712,341	8,859,079	52,815,964
Total change in net assets	**17,444,902**	**27,663,387**	**9,022,014**	**54,130,303**
Net assets beginning	147,793,560	57,017,940	50,837,543	255,649,043
Net assets ending	**$165,238,462**	**$84,681,327**	**$59,859,557**	**$309,779,346**

The accompanying notes are an integral part of the financial statements.

Statement of Activities

for the year ended June 30,1997

	Unrestricted	Temporarily Restricted	Permanently Restricted	Total
Operating revenues:				
Tuition and fees	$ 49,183,646	$ –	$ –	$ 49,183,646
Less: Unrestricted student aid	14,020,126	–	–	14,020,126
Endowed scholarships	1,932,388	–	–	1,932,388
Externally funded student aid	2,657,544	–	–	2,657,544
Total student aid	**18,610,058**	–	–	**18,610,058**
Net tuition and fees	30,573,588			30,573,588
Other educational operations	8,746,894	–	–	8,746,894
Contributions	4,607,189	1,905,473	–	6,512,662
Contract and exchange transactions	12,994,866	–	–	12,994,866
Investment income on endowment	3,589,360	–	21,089	3,610,449
Net realized and unrealized gains on endowment, expended	2,184,240	1,645,167	50,770	3,880,177
Other investment income	1,845,133	293,742	37,864	2,176,739
Gain on sale of real estate	497,240	–	–	497,240
Sales and services of auxiliary enterprises	8,052,947	–	–	8,052,947
Other	739,976	–	–	739,976
Total revenues	**73,831,433**	**3,844,382**	**109,723**	**77,785,538**
Net assets released from restriction	2,507,185	(2,507,185)	–	–
Total revenues and other support	**76,338,618**	**1,337,197**	**109,723**	**77,785,538**
Operating expenses:				
Instruction and department research	33,517,942	–	–	33,517,942
Sponsored research	7,518,009	–	–	7,518,009
External relations	2,700,718	–	–	2,700,718
Institution and academic support	10,479,718	–	–	10,479,718
Student services	4,474,395	–	–	4,474,395
Operation and maintenance of plant	12,167,421	–	–	12,167,421
Auxiliary enterprises	6,138,289	–	–	6,138,289
Total operating expenses	**76,996,492**	–	–	**76,996,492**
Change in net assets from operating activities	(657,874)	1,337,197	109,723	789,046
Nonoperating:				
Realized and unrealized gains	17,828,141	13,961,195	309,577	32,098,913
Loss on refinancing	(3,204,727)			(3,204,727)
Contributions		549,267	1,196,015	1,745,282
Change in net assets from nonoperating activities	14,623,414	14,510,462	1,505,592	30,639,468
Total change in net assets	13,965,540	15,847,659	1,615,315	31,428,514
Net assets beginning	133,828,020	41,170,281	49,222,228	224,220,529
Net assets ending	$147,793,560	$57,017,940	$50,837,543	$255,649,043

The accompanying notes are an integral part of the financial statements.

Statements of Cash Flows

for the years ended June 30, 1998 and 1997

	1998	1997
Cash flows from operating activities:		
Change in net assets	$ 54,130,303	$ 31,428,514
Adjustments to reconcile change in net assets to net cash provided by operating activities:		
Depreciation and amortization	6,692,684	6,558,383
Loss on refinancing	–	3,204,727
Change in the value of split-interest agreements	(22,629)	–
Provision for bad debt	(82,658)	(109,156)
Contributions other than cash	(3,692,158)	(797,306)
Increase in annuities payable	733,538	114,033
Net realized and unrealized gain on investments	(34,402,488)	(36,332,223)
Gain on sale of land	(23,500)	(497,240)
Contributions restricted for long-term investments	(3,086,210)	(1,196,015)
Changes in operating assets and liabilities:		
Accounts receivable	(427,830)	(150,978)
Contributions receivable	(12,258,518)	(1,317,764)
Notes receivable	14,314	(391,289)
Prepaids and other assets	10,983	123,018
Funds held for others	78,751	(1,167)
Accounts payable and accrued expenses	643,107	1,212,467
Annuities payable	(204,918)	(22,685)
Deferred revenue	(202,994)	499,223
Net cash provided by operating activities	7,899,777	2,324,542
Cash flows from investing activities:		
Proceeds from sales and maturities of investments	158,649,831	89,090,801
Purchases of investments	(163,613,542)	(82,634,807)
Disposal of plant assets	196,151	–
Proceeds from sales of land	23,500	497,240
Purchase of land, building, and equipment	(8,495,841)	(6,240,054)
Disbursement of loans to students	(2,696,970)	(2,376,177)
Repayments of loans from students	1,812,303	1,771,954
Net cash provided by (used in) investing activities	(14,124,568)	108,957
Cash flows from financing activities:		
Receipts of refundable government loan funds	180,968	155,712
Contributions restricted for long-term investments	3,086,210	1,196,015
Deposits with trustees	5,061,567	(20,915,213)
Proceeds from issuance of debt, net of discount	–	61,741,874
Repayment of indebtedness	(1,677,039)	(37,928,021)
Debt issuance costs paid	–	(1,107,321)
Net cash provided by financing activities	6,651,706	3,143,046
Net increase in cash and cash equivalents	426,915	5,576,545
Cash and cash equivalents, beginning	14,473,586	8,897,041
Cash and cash equivalents, ending	**$ 14,900,501**	**$ 14,473,586**
Supplemental cash flow information:		
Interest paid	**$ 3,107,169**	**$ 2,536,402**

The accompanying notes are an integral part of the financial statements.

NOTES TO FINANCIAL STATEMENTS

1. Organization and Summary of Significant Accounting Policies

Background Worcester Polytechnic Institute ("WPI" or the "University"), founded in 1865, is the nation's third oldest private engineering college. Approximately 3,830 undergraduate and graduate students attend WPI annually. WPI is located in Worcester, Massachusetts, and serves a diverse student base from 44 states and 64 countries.

Basis of Financial Statement Presentation: The accompanying financial statements are presented on the accrual basis of accounting and have been prepared to focus on WPI as a whole and to present balances and transactions according to the existence or absence of donor-imposed restrictions.

WPI has defined its primary activities as operating and nonoperating. Operating activities consist primarily of activities supporting the educational mission and purpose of WPI. Nonoperating activities consist primarily of endowment gifts, unspent appreciation on endowment, and contributions for capital use.

Net assets and revenues, expenses, gains and losses were classified based on the existence or absence of donor-imposed restrictions. Accordingly, net assets and changes therein are classified as follows:

Permanently Restricted Net Assets Net assets subject to donor-imposed stipulations that they be maintained permanently by the University. Generally, the donors of these assets permit the institution to use all or part of the income earned on related investments for general or specific purposes.

Temporarily Restricted Net Assets Net assets whose use is restricted by state law or subject to donor-imposed stipulations that may or will be met by actions of WPI and/or the passage of time.

Unrestricted Net Assets Net assets not subject to donor-imposed stipulations.

Revenues are reported as increases in unrestricted net assets unless use of the related assets is limited by donor-imposed restrictions. Expenses are reported as decreases in unrestricted net assets. Gains and losses on investments and other assets or liabilities are reported as increases or decreases in unrestricted net assets unless their use is restricted by explicit donor stipulation or by law. Expirations of temporary restrictions on net assets (that is, the donor-stipulated purpose has been fulfilled and/or the stipulated time period has elapsed) are reported as reclassifications between the applicable classes of net assets.

Permanently restricted net assets consist of the following:

	1998	1997
Endowment funds - original principal	$ 52,189,780	$ 45,022,083
Split-interest agreements and perpetual trusts	6,069,580	4,305,129
Student loan funds	1,600,197	1,510,331
	$ 59,859,557	**$ 50,837,543**

Temporarily restricted net assets consist of the following:

	1998	1997
Gifts and other unexpended revenues:		
Instruction, research, and institutional support	$ 14,285,725	$ 2,661,743
Acquisition of building and equipment	3,229,294	2,126,591
	17,515,019	4,788,334
Endowment funds - unspent income and appreciation	59,379,949	46,645,637
Split-interest agreements and perpetual trusts	7,786,359	5,583,969
	$ 84,681,327	**$ 57,017,940**

Years ending June 30	1988 dollars (millions) 1997	1988 dollars (millions) 1998	Current dollars (millions) 1997	Current dollars (millions) 1998
Total Operating Revenues (Net of Student Aid)	56.7	58.2	77.8	81.3
Total Operating Expenses	56.1	57.3	77.0	80.0
Tuition and Fees Revenues (Net of Student Aid)	22.3	23.1	30.6	32.2

At June 30, 1998 and 1997, substantially all of the University's unrestricted net assets were designated for specific purposes, as follows:

	1998	1997
Long-term investment (quasi-endowment funds)	$ 139,293,261	$ 120,878,921
Net investment in plant facilities	21,509,398	23,112,098
Loans to students	4,435,803	3,802,541
	$ 165,238,462	**$ 147,793,560**

Gifts and Pledges Contributions, including unconditional promises to give, are recognized as revenues in the period received. Conditional promises to give are not recognized until they become unconditional, that is when the conditions on which they depend are substantially met. The net assets of the Alumni Association of WPI, a separate 501(c)(3) corporation, are not reflected on the books of WPI. Net assets were approximately $1.9M and $1.6M at June 30, 1998 and 1997, respectively. Contributions of assets other than cash are recorded at their estimated fair value at the date received. Contributions to be received after one year are discounted at a rate of 6%. Amortization of the discount is recorded as additional contribution revenue in accordance with donor-imposed restrictions, if any, on the contributions. An allowance for uncollectible contributions receivable is provided based upon management's judgment including such factors as prior collection history, type of contribution and nature of fund-raising activity.

At June 30, 1997, conditional promises to give, consisting of bequests, not reflected in the financial statements were $4,965,000.

Contributions with Restrictions Met in the Same Year Contributions, received with donor-imposed restrictions that are met in the same year as received, are reported as revenues of the unrestricted net asset class.

Release of Restrictions on Net Assets for Acquisition of Land, Building and Equipment Contributions of land, building and equipment without donor stipulations concerning the use of such long-lived assets are reported as revenues of the unrestricted net asset class. Contributions of cash and other assets to be used to acquire land, building and equipment with such donor stipulations are reported as revenues of the temporarily restricted net asset class. The restrictions are considered to be released at the time of acquisition of such long-lived assets.

Cash and Cash Equivalents Cash and cash equivalents include cash on hand and short-term investments with maturities of 90 days or less when purchased.

Inventories Inventories, consisting principally of alumni souvenirs, are valued at the lower of cost (first-in, first-out) or market.

Deferred Financing Costs Deferred financing costs relate to debt issuance costs which are amortized over the life of the bonds. Total amortization expense for the years ended June 30, 1998 and 1997, was $82,583 and $68,783, respectively.

Sponsored Research Revenues associated with research and other contracts and grants at the University are recognized as related costs are incurred. Indirect cost recovery by the University is based on a predetermined rate.

Property, Plant and Equipment Land and land improvements, buildings and equipment are recorded at cost at the date of purchase. When assets are retired or otherwise disposed of, the cost and related accumulated depreciation are removed from the accounts, and any resulting gain or loss is reflected in operation for the period. The cost of maintenance and repairs is charged to income as incurred, significant renewals and betterments are capitalized.

WPI depreciates capital assets based upon their useful lives. The policy applies to assets acquired with an expected useful life of three years or more and a cost greater than $500. Depreciation is calculated using the straight-line method, half-year convention over the following estimated useful lives:

Land improvements	10 - 20 years
Buildings and improvements	20 - 40 years
Equipment	3 - 10 years

Depreciation expense for the years ended June 30, 1998 and 1997, was $6,593,354 and $6,489,600, respectively.

Years ending June 30	1988 dollars (millions) 1997	1988 dollars (millions) 1998	Current dollars (millions) 1997	Current dollars (millions) 1998
Operations and Plant Maintenance Expenditures	8.9	9.2	12.2	12.8
Instruction and Department Research	24.4	25.3	33.5	35.4

Tuition and Fees as a Percent of Total Operating Revenues **1997**/39.3% **1998**/39.6%

Split-Interest Agreements and Perpetual Trusts The University has split-interest agreements with donors consisting primarily of charitable gift annuities, pooled-income funds and irrevocable charitable remainder trusts. Assets held in trust are separately invested and are included in intermediate and long-term investments on the statement of financial position. Income distributions are made to beneficiaries in accordance with the trust agreements.

Contribution revenues for charitable gift annuities and charitable remainder trusts are recognized at the dates the agreements are established, after recording liabilities for the present value of the estimated future payments to be made to the respective donors and/or beneficiaries. For pooled income funds, contribution revenue is recognized upon the establishment of the agreements as the fair value of the estimated receipts, discounted for the estimated time period to complete the agreements. Such contributions, net of the related liabilities, are classified as increases in temporarily or permanently restricted net assets based on donor-imposed stipulations.

The present value of payments to beneficiaries of charitable gift annuities and charitable remainder trusts and the estimated future receipts from pooled income funds are calculated using discount rates from 6.8% to 8%.

Tax-Exempt Status The University is exempt from federal income tax under Section 501(c)(3) of the Internal Revenue Code.

Use of Estimates in the Preparation of Financial Statements The preparation of the financial statements in conformity with generally accepted accounting principles requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from those estimates.

Reclassification Certain 1997 amounts have been reclassified to conform to current year presentation.

2. Accounts Receivable

Accounts receivable consist of the following:

	1998	1997
Sponsored research	$ 1,715,307	$ 1,976,983
Other receivables	2,778,376	2,057,165
	4,493,683	4,034,148
Less: allowance for doubtful accounts	370,510	368,573
Total accounts receivable	**$ 4,123,173**	**$ 3,665,575**

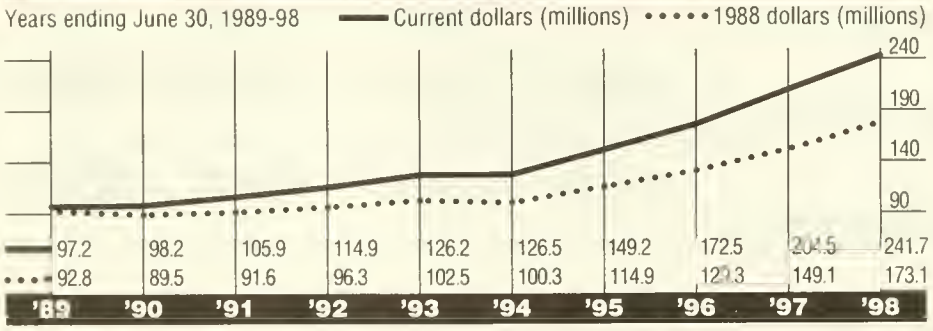
3. Notes Receivable

Notes receivable consist of the following at June 30, 1998 and 1997:

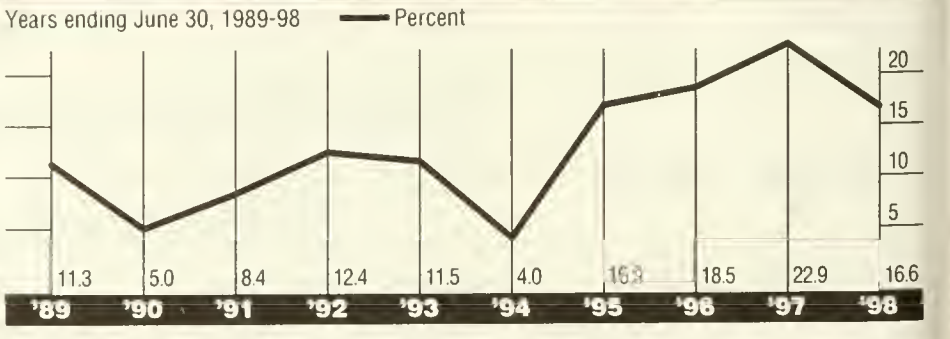
	1998	1997
Student loans	$ 15,088,178	$ 14,203,511
Other	485,652	499,966
	15,573,830	14,703,477
Less: allowance for doubtful accounts	11,398	11,398
Total notes receivable	**$ 15,562,432**	**$14,692,079**

Notes receivable are principally amounts due from students under federally sponsored loan programs which are subject to significant restrictions. Accordingly, it is not practicable to determine the fair value of such amounts.

Market Value of Endowment



Endowment Total Return



4. Contributions Receivable

Unconditional promises at June 30, 1998 and 1997, are expected to be realized in the following periods:

	1998	1997
In one year or less	$ 6,857,052	$ 1,068,670
Between one and five years	6,755,503	1,184,569
Greater than five years	4,408,896	340,000
	18,021,451	2,593,239
Less:		
Discount	2,590,143	223,000
Allowance	941,893	177,000
	$ 14,489,415	**$ 2,193,239**

5. Property, Plant and Equipment

Property, plant and equipment consists of the following at June 30, 1998 and 1997:

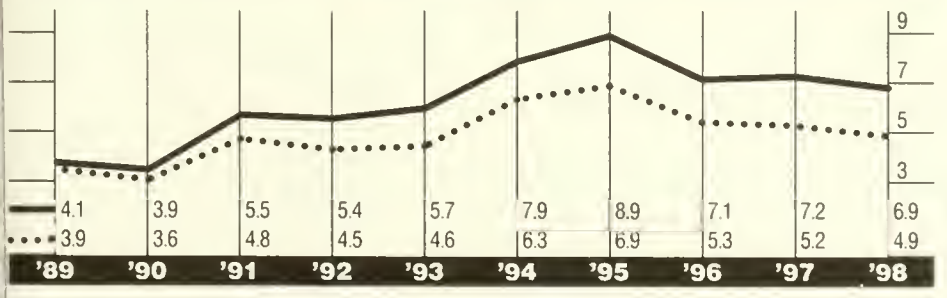
	1998	1997
Land and land improvements	$ 7,020,440	$ 5,602,193
Buildings	82,583,433	79,685,627
Equipment	27,610,788	26,008,749
Construction in progress	3,811,834	1,430,237
	121,026,495	112,726,806
Less: accumulated depreciation	55,569,878	48,976,525
	$ 65,456,617	**$ 63,750,281**

6. Investments

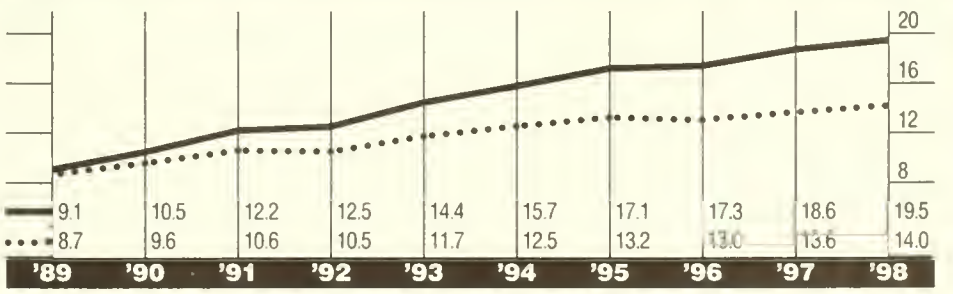
Investments in equities, bonds, mutual funds, and funds held in trust by others have been reported in the financial statements at fair value. Investment in the realty trust is reflected at cost. Fair values for investments held through limited partnerships are estimated by the respective external investment managers if fair values are not readily ascertainable. Cash and investments at June 30, 1998, were as follows (comparative totals are included for 1997):

	1998				1997
	Endowment	Split-Interest Agreements	Other	Total	Total
Cash and cash equivalents	$ 9,464,283	$ 105,515	$ 5,330,703	$ 14,900,501	$ 14,473,586
Equities	125,838,597	6,582,007	109,524	132,530,128	111,955,820
Bonds	16,326,330	7,462,376	112,485	23,901,191	21,889,472
Mutual funds:					
Equity funds	39,666,781	–	–	39,666,781	39,921,678
Fixed income funds	48,420,659	–	235,931	48,656,590	24,521,772
Venture capital	5,081,015	–	–	5,081,015	7,935,611
Realty trust	2,325,150	–	–	2,325,150	2,682,000
Oil and gas, L.P	574,783	–	–	574,783	3,459,831
Bioventures, L.P	626,727	–	–	626,727	608,505
Other partnerships	1,094,620	–	–	1,094,620	861,198
Real estate	5,026,801	128,000	–	5,154,801	5,154,800
Funds held in trust by others	–	4,493,389	–	4,493,389	2,056,131
Total intermediate and long-term investments	244,981,463	18,665,772	457,940	264,105,175	221,046,818
Total	**$254,445,746**	**$18,771,287**	**$5,788,643**	**$279,005,676**	**$235,520,404**

Sponsored Program Awards



Student Aid



Endowment Income and Spending At June 30, 1998, there was a total of 49,701,518 units, each having a market value of $4.916. Of the total units, 21,297,546 were owned by endowment funds and 28,403,972 were owned by internally designated funds.

A summary of the market value per unit and the income per time-weighted unit for the pooled investments held as of June 30, 1998, and in each of the prior four years is as follows:

	Income Per Time Weighted Unit	Market Value Per Unit
1998	$ 0.100	$ 4.916
1997	0.079	4.345
1996	0.106	3.698
1995	0.114	3.190
1994	0.094	2.968

The University observes a spending rule with respect to unrestricted investment income on investments of the endowment. In accordance with that spending rule, the University distributed 5.5% of the average unit market value for the previous two years to current operations.

The spending rule distributions for fiscal 1998 and 1997, respectively, were .189 and .169 per time weighted unit which were comprised of .100 and .079 of income per time-weighted unit and .089 and .090 per unit distributed from accumulated capital gains.

Intermediate and long-term investments at June 30, 1998 and 1997, include the following split-interest agreements:

	1998	1997
Charitable gift annuities	$ 3,663,168	$ 3,047,459
Charitable remainder trusts	7,397,008	5,457,296
Pooled income funds	3,112,206	2,873,097
Perpetual trusts	4,493,390	2,056,131
	$ 18,665,772	**$ 13,433,983**

Investment Return The investment return in the statement of activities for the year ended June 30, 1998, with comparative totals for 1997 can be summarized as follows:

	1998				1997
	Unrestricted	Temporarily Restricted	Permanently Restricted	Total	
Investment income	$ 4,572,678	$ 2,854	$ 65,254	$ 4,640,786	$ 3,610,449
Net realized and unrealized gains	18,302,102	15,325,871	343,698	33,971,671	35,979,090
Return on endowment	22,874,780	15,328,725	408,952	38,612,457	39,589,539
Other investment income	2,756,015	94,026	39,595	2,889,636	2,176,739
Total return on investments	**25,630,795**	**15,422,751**	**448,547**	**41,502,093**	**41,766,278**
Investment return designated for current operations	9,517,225	1,793,167	162,935	11,473,327	9,667,365
Investment return in excess of amount designated for current operation	**$16,113,570**	**$13,629,584**	**$285,612**	**$30,028,766**	**$32,098,913**

Investment income is net of management expenses of $1,821,767 and $1,653,855 for the years ended June 30, 1998 and 1997, respectively.

7. Long-Term Debt

Long-term debt at June 30, 1998, amounted to $64,722,230. Schedule I summarizes the components of long-term debt. The aggregate amounts of principal due for each of the next five fiscal years are as follows:

1999	$ 1,625,936
2000	1,839,251
2001	2,497,190
2002	5,585,299
2003	2,208,129

On February 15, 1997, WPI deposited with Trustees sufficient funds to prepay in full HEFA Series C and Series E Bonds which mature September 1, 2000, and September 1, 2017, respectively. WPI issued Massachusetts Industrial Finance Agency Series I bonds of $29,855,000 in connection with the refinancing. (See Schedule 1) WPI recognized a loss of approximately $3.2 million in fiscal 1997 on the refinancing. However, a net present value savings will be realized over the life of the bonds.

During fiscal 1997 WPI prepaid in full HEFA Series J1 and J2 loans. WPI issued MIFA Series II bonds of $29,600,000 which included proceeds for the retirement of these HEFA loans.

In compliance with the University's various bond indentures, deposits with Trustees at June 30, 1998 and 1997, include investments in debt service and reserve funds of $16,928,178 and $21,989,745, respectively.

The University entered into an interest rate swap agreement with an investment broker in November 1991 in order to reduce the cost of borrowing on its HEFA Series C and E bonds. The swap had a notional principal amount of $30 million and effectively changed the interest rate exposure on the Series C and E bonds to a variable rate based on a specified bond index. The swap agreement terminated in December 1996. The University recognized income from the swap of approximately $165,000 during fiscal year 1997 which is included in other investment income in unrestricted net assets. The Series C and E bonds were refunded in February 1997.

In April 1994, WPI entered into a second six-year swap agreement (the "Agreement") for a notional amount of $30 million in order to further reduce its cost of borrowing. The Agreement terminates in fiscal 1999 and calls for the receipt of fixed payments by the counterparty at 4.85% of the notional amount in exchange for variable payments on an equivalent amount based on the PSA Municipal Bond Index. In March 1996, the University amended the Agreement to receive fixed payments from the counterparty through June 1999 of $63,000 per quarter. In fiscal 1998 and 1997, the University recognized income of approximately $252,000 from the Agreement which is included in other investment income in unrestricted net assets. The fair value of the Agreement at June 30, 1998, was approximately $238,000, which represents the present value of the future payments to be received by the University.

In February 1998, WPI entered into an interest rate swap agreement in order to reduce the cost of borrowing on its unsecured Fleet note. The swap changed the interest rate exposure on the Fleet note from a variable rate of LIBOR plus .135 to a fixed interest rate of 7%.

The University is exposed to credit risk in the event of nonperformance by the counterparty. The counterparty to the Agreement is an established investment bank and the University does not anticipate nonperformance by the counterparty.

Note 6, Schedule I, Summary of Bonds, Notes and Mortgages Payble
June 30, 1998

Purpose and Definition	Maturity Date	Interest Rate %	Original Issue	Amount Due Within One Year	Balance June 30, 1998
Bonds Payable:					
Housing and Urban Development:					
Series B - April 1, 1969 (2)	4/1/01	3.375	919,000	45,000	124,000
Series C - April 1, 1969 (3)	4/1/19	3.00	1,160,000	25,000	702,000
				70,000	826,000
Massachusetts Health and Educational Facilities Authority:					
Series A - July 1, 1977 (3)	7/1/03	4.7 - 5.3	4,150,000	200,000	1,110,000
Massachusetts Industrial Finance Agency:					
Series I (4)	9/1/17	5.11	–	1,020,000	28,685,814
Series II (5)	9/1/27	4.1 - 5.5	–	–	29,291,954
				1,020,000	57,977,768
Mortgage Payable:					
Ellsworth-Fuller Student Residence Center (6)	12/31/03	7.25	1,950,000	110,936	720,962
Unsecured Notes:					
Fleet Bank - 9/28/93	9/01/01	7.00	4,500,000	225,000	4,087,500
Total bonds and mortgages payable (7)				**$1,625,936**	**$64,722,230**

(1) Collateralized by land, building and equipment known as Daniels Hall (carried on the accounts at $562,862) and pledged net revenues from the operations of the dormitory and bookstore located therein.

(2) Collateralized by land, building and equipment known as Stoddard Residence Center (carried on the accounts at $747,424) and pledged net revenues from the operations of the dormitory and health center located therein.

(3) Pledged as collateral are $1,221,000 of internally designated endowment funds equal to 110% of the principal amount of the bonds outstanding which are held by a Trustee in the Debt Service Reserve Fund. Various academic revenues are pledged for the HEFA Series A bonds.

(4) The bonds are not secured by a mortgage lien on security interest in any real property or revenues of the University and represent a general obligation of the University. The balance at June 30, 1998, is net of a discount of $103,978.

(5) The bonds are not secured by a mortgage lien on security interest in any real property or revenues of the University and represent a general obligation of the University. The balance at June 30, 1998, is net of a discount of $331,416.

(6) Interest is at 7 1/4%, of which 3% is paid by WPI and the balance is paid by the U.S. Department of Housing and Urban Development.

(7) The total amount outstanding at June 30, 1998, approximates fair value based on estimates using current interest rates available for debt with the same remaining maturities.

8. Pension Plans

WPI contributes to a defined contribution plan (TIAA-CREF) for academic and nonacademic personnel. Contributions to TIAA-CREF are based on a percentage of payroll. The University's pension costs amounted to $2,671,278 and $2,506,185 for the fiscal years ended in 1998 and 1997, respectively.

9. Commitments

During fiscal year 1998, WPI entered into additional commitments with several limited partnerships to invest $6,000,000, bringing the cumulative total to $14,000,000. These partnerships invest in venture capital. As of June 30, 1998, WPI has funded approximately $5,000,000, and has remaining commitments under the agreements of approximately $9,000,000.

The University has guaranteed commercial loans of $2,125,000 to four fraternities. These annual loans are collateralized by real property owned by the fraternities.

WPI is obligated under noncancelable operating leases for various facilities and equipment. Assets under these lease agreements consist of office furniture, computer equipment, office space and storage facilities.

Commitments under noncancelable operating leases provide for minimum rental payments for the next five fiscal years of:

1999	$ 347,643
2000	284,208
2001	284,208
2002	19,200
	$ 935,259

Rental expense was $405,359 and $335,909 for the years ended June 30, 1998 and 1997, respectively.

10. Contingencies

WPI has pending several cases which have arisen in the normal course of operations. WPI believes that the outcome of these cases will have no material adverse effect on the University's financial position.

The University's sponsored research program and indirect cost recovery are subject to the future audits by the respective sponsoring federal agency as provided for in federal sponsored research regulations. Management believes that such audits will not have a materially adverse effect on WPI's financial position.

11. Expenses by Functional Category

Following is a schedule of expenses by functional category:

	1998	1997
Instruction and department research	$ 41,091,499	$ 39,001,424
Sponsored research	6,889,248	8,256,526
External relations	3,118,888	2,700,718
Institution and academic support	15,510,312	14,275,419
Student services	4,896,779	4,474,395
Auxiliary enterprises	8,481,728	8,288,010
	$79,988,454	**$76,996,492**

Depreciation, maintenance, interest and other expenses have been functionalized. Methods in allocating these expenses include actual expenses incurred and percentage of square footage for each functional area.

External relations expenditures include $3,028,888 and $2,631,766 of fund-raising expenses for the years ended June 30, 1998 and 1997, respectively.

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Record Year Sets Stage for Campaign

By John L. Heyl, Vice President for University Relations

For the Office of Development and University Relations, 1997-98 was spent setting the stage for the future, a future that will be dominated by a major capital campaign in the near term. After a few years of planning and quiet fund raising, WPI is set to launch the Campaign for WPI in April. By far the most ambitious development effort in the University's history, the campaign will raise the resources needed to achieve WPI's strategic goals for the future (see The Year in Review, page 12).

The campaign will be kicked off on the heels of WPI's most successful fund-raising year ever. In 1997-98 the University received nearly $16.5 million in gifts of cash and gifts-in-kind, or $1.8 million more than we raised in the previous record-setting year. A new record was also set for our annual giving program, which raised more than $1.5 million in funds that can be spent immediately to help WPI meet the expenses associated with providing a high-quality education to its students. The kudos for this exceptional performance go to the Alumni Funds Board and its chair, Harry W. Tenney Jr. '56, and the annual giving staff.

WPI revamped its alumni fund-raising organization last year, creating the Alumni Funds Board to oversee all alumni fund raising and to establish a class-based volunteer structure. Also established last year was the Annual Alumni Fund Committee, formed to solicit annual operational gifts from alumni. Of the committee's 15 members, 12 are charged with helping recruit and motivate volunteers in five-year class ranges. Class volunteer structures fall into the categories of reunion, anniversary and nonreunion/nonanniversary. The reunion program got off to a good start last fall with 15 classes launching three-year reunion campaigns.

The trend toward record setting was also in evidence in our planned and deferred giving programs. In 1997-98, 47 individuals contributed a record $3.3 million through deferred gift arrangements, such as charitable gift annuities, pooled-income funds and charitable remainder trusts. Equally unprecedented was the more than $5 million in gifts received from the estates of 21 WPI alumni and their families. Among them was the $2.6 million bequest from Harry Sorenson '30, the second largest gift in WPI history (see page 13).

A magnificent gift from the George I. Alden Trust, also received in 1997-98, equaled the largest gift in the history of the University: the $5 million bequest from

By far the most ambitious development effort in the University's history, the campaign will raise the resources needed to achieve WPI's strategic goals for the future.

George C. Gordon, Class of 1895, that made possible the construction of Gordon Library. The gift from the Alden Trust will support the construction of a new academic building. Founded by WPI's first professor of mechanical engineering, the trust is WPI's greatest benefactor. Since 1920, it has awarded WPI $10.8 million, not including this most recent gift. The most visible evidence of that generosity is Alden Memorial, completed in 1940 as a gift from the trust. Since then, the trust has supported the construction of Fuller Laboratories and the renovation of Salisbury Laboratories, Alden Memorial and Higgins Laboratories.

Development and University Relations is about more than fund raising, and last year the office reorganized to best fulfill all three of its missions: raising resources for the University, enhancing the University's image and reputation, and building strong ties between WPI and its alumni. To build a cohesive and well-coordinated fund-raising program, we placed all of our development operations—annual giving, planned giving, major gifts, corporate relations, development research, alumni record keeping and gift recording—under the leadership of one individual, Robert G. Dietrich, director of development. We have also brought all of these functions together on the third floor of Boynton Hall.

In another move aimed at creating greater synergy, we merged our media and community relations and publications offices to form the Communications Group, under the direction of Michael W. Dorsey, director of communications. The group, located in a house just off the main campus, will play important roles in developing new marketing and communications strategies to support the University's goal of becoming a nationally known institution.

The Alumni Office, led by Tina Gorski-Strong, director of alumni affairs, continued to look to the future of alumni relations at WPI as it worked with the WPI Alumni Association on the development and implementation of a new five-year master plan (see page 13).

The year ahead promises to be among the most important and eventful in the history of this office and in the history of the University. With the completion of a strategic plan and the start of a capital campaign, WPI will be taking critical steps along a path that will carry us toward greater quality and prestige. It promises to be an exciting journey.

Staff of the *WPI Journal*: Editor, Michael W. Dorsey • Managing Editor, Bonnie Gelbwasser • Alumni Editor, Joan Killough-Miller • Art Director, Michael J. Sherman •
Alumni Publications Committee: Robert C. Labonté '54, chairman, Kimberly A. (Lemoi) Bowers '90, James S. Demetry '58, William J. Firla Jr. '60, Joel P. Greene '69, William R. Grogan '46, Roger N. Perry Jr. '45, Harlan B. Williams '50 • The *WPI Journal* (ISSN 0148-6128) is published quarterly for the WPI Alumni Association by the Office of University Relations. Periodicals postage paid at Worcester, Mass., and additional mailing offices. Printed by The Lane Press, Burlington, Vt. Printed in the U.S.A.

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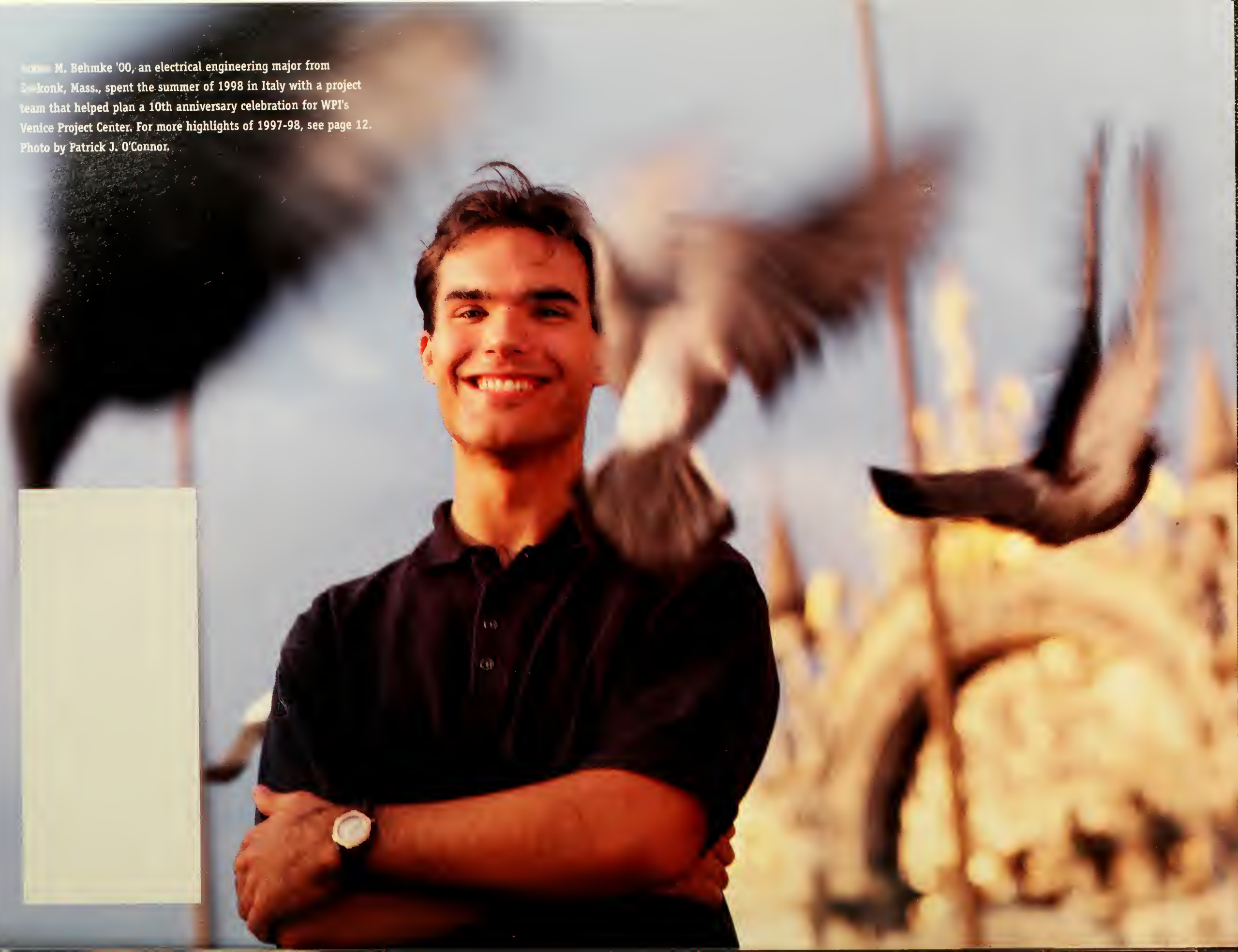
[redacted] M. Behmke '00, an electrical engineering major from [redacted]konk, Mass., spent the summer of 1998 in Italy with a project team that helped plan a 10th anniversary celebration for WPI's Venice Project Center. For more highlights of 1997-98, see page 12. Photo by Patrick J. O'Connor.



◆ 21st Century Pharmacy ◆ All That Jazz ◆ The Hybrid Reborn

WPI Journal

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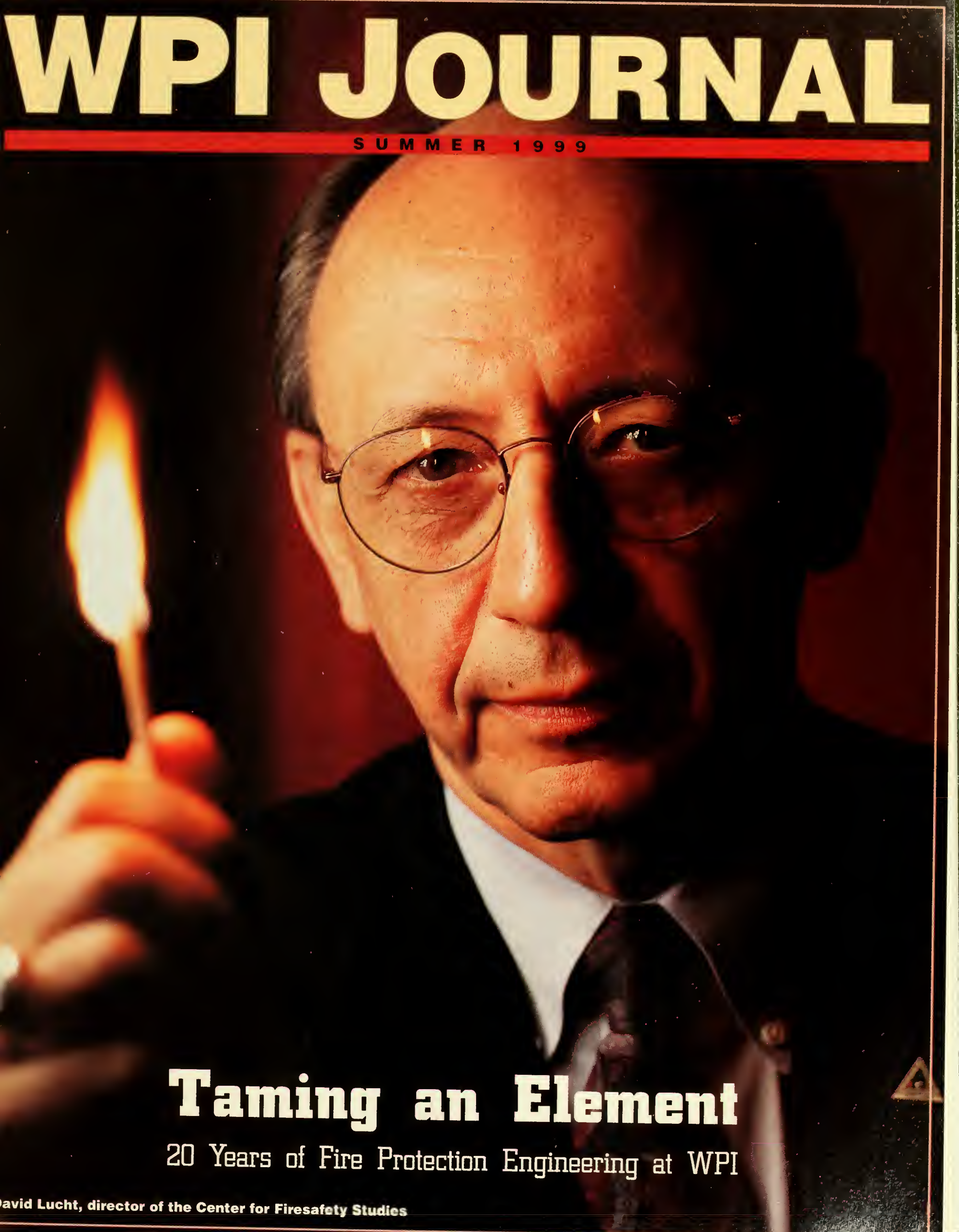


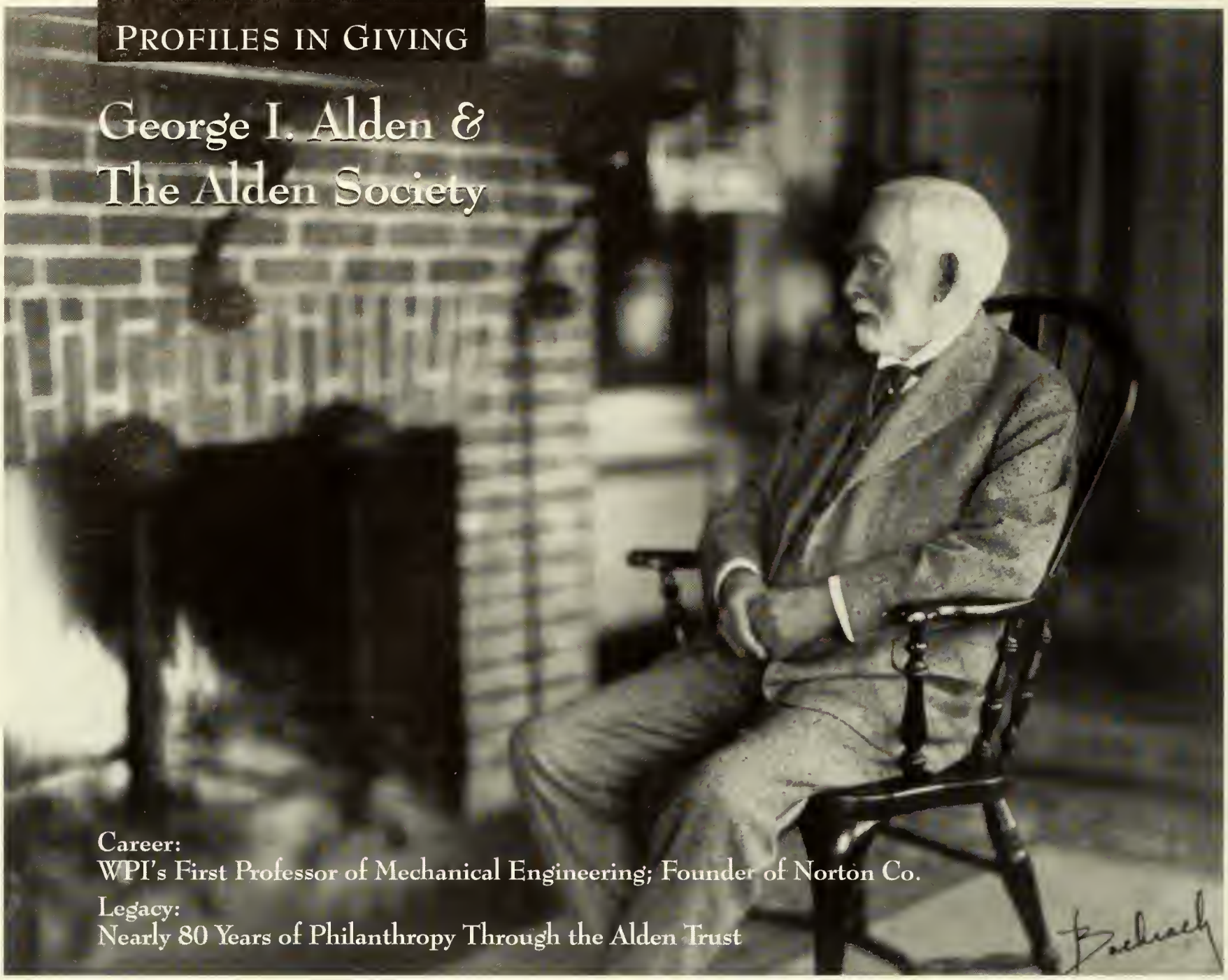
Taming an Element

20 Years of Fire Protection Engineering at WPI

David Lucht, director of the Center for Firesafety Studies

PROFILES IN GIVING

George I. Alden & The Alden Society



Career:
WPI's First Professor of Mechanical Engineering; Founder of Norton Co.

Legacy:
Nearly 80 Years of Philanthropy Through the Alden Trust

— On Merging Theory and Practice —

George I. Alden began his relationship with WPI when he and four other instructors welcomed WPI's first class on Nov. 11, 1868. As WPI's first professor and department head in mechanical engineering, he helped shape the school's founding principle of merging theory with practical experience. Through his work as an educator and a researcher in hydraulics, he also spread the school's reputation far beyond the campus, and he established the predecessor to Otis Elevator Co. and Worcester's own Norton Co. He achieved great success in his business endeavors, but never forgot the importance of education or the institution where his career began.

— On Creating a Lasting Legacy —

During his lifetime, George Alden established a philanthropic trust to continue his support for education and for WPI after his death. Today, the George I. Alden Trust is recognized as WPI's greatest benefactor, with commitments to date totaling over $16 million. Through the years, Alden's generosity and his foresight have inspired many of WPI's alumni and friends. WPI's Alden Society commemorates Alden's unique legacy and recognizes a new generation of WPI benefactors whose generosity, through current planned gift arrangements or the intention of a future gift through their estate plans, will help sustain the University well into the 21st century.

Membership in the Alden Society includes the original charter members and is also open to others who choose to make a future gift to WPI. Commitments may take the form of contributions to one of WPI's two pooled-income funds, the creation of a charitable remainder trust, participation in WPI's gift annuity program, naming WPI as a beneficiary of a life insurance policy or a qualified retirement plan, or inclusion of WPI in one's will or living trust. For more information, please contact Liz Siladi, director of planned giving, at 1-888-974-4438, or return the reply card in this issue of the WPI Journal.

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WPI JOURNAL

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Jazz hipster, inspired educator, accomplished musician, Rich Falco has spent the past two decades building an honored spot for WPI in the jazz landscape.

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Front Cover: David Lucht, director of the Center for Firesafety Studies, has been the guiding light behind WPI's world-renowned program in fire protection engineering. Story on page 4. Photo by Patrick O'Connor. Back Cover: The Star-Spangled Banner is a powerful symbol of the struggle to keep America safe from tyranny. Work by a WPI graduate will keep the delicate flag safe from the threat of fire. Story on page 15. Photo courtesy the Smithsonian Institution.

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Mathematicians Study the Properties That Bind Things Together and Blow Them Apart

Research That's Truly Explosive

With funding from the Department of Energy, a team of researchers from WPI will spend the next five to 10 years creating computer simulations of fires and explosions. The team, led by **Homer Walker,** head of the Mathematical Sciences Department, is part of a group of American mathematicians and scientists working on similar research.

Along with Walker, Marcus Sarkis, assistant professor of mathematical sciences at WPI, and Michael Tocci '92, a mathematical sciences research associate, are collaborating with their counterparts at the University of Utah's Center for Simulation of Accidental Fires and Explosions (C-SAFE). Walker was a mathematics professor at Utah State University and a member of the C-SAFE team before he came to WPI in 1997.

PATRICK O'CONNOR

The DOE established C-SAFE with a five-year, $26.8 million contract through its Accelerated Strategic Computing Initiative (ASCI), a program designed to improve the safety and security of the nation's nuclear stockpile. The agency also funded similar centers at Caltech, Stanford, the University of Chicago and the University of Illinois at Urbana-Champaign. (None of the work at these university centers is classified or involves nuclear weapons.)

"The overall goal of C-SAFE is to develop an integrated problem-solving environment that will effectively exploit the power of massively parallel computers to carry out 'full-physics' simulation of fire scenarios involving hydrocarbon liquids, chemical explosives, containers and other structures," Walker says. "At WPI, we will focus on developing numerical algorithms and software to solve extremely large problems—ultimately involving billions of equations and unknowns. We will use a new generation of massively parallel computers, the most powerful in the world, which have been installed at the national laboratories."

"We will focus on developing numerical algorithms and software to solve extremely large problems —ultimately involving billions of equations and unknowns."

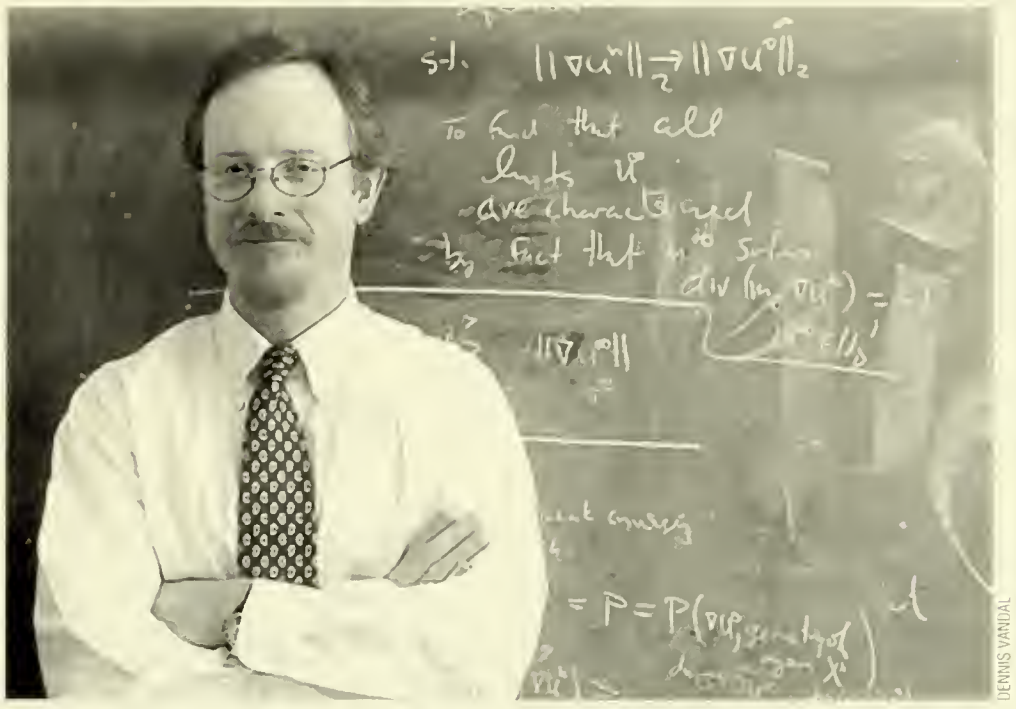
Possible scenarios that may be investigated on these computers include a fire at an explosives manufacturing plant or the crash of an airplane carrying explosives. "The simulations will be based on 'first principles' of physics and chemistry that model fuel combustion, the coupled flow of combusting gases above the fuel, the transport of heat and the ultimate combustion of the materials, among other factors," Walker says.

A high-performance parallel computer will make possible the complex computations. Funding for the computer has been provided by a $145,000 grant from the National Science Foundation, with additional support from United Technologies Corp. and WPI research funds.

"This machine will be a major computing resource for this and many other research and educational activities in the Mathematical Sciences Department and elsewhere on campus," says Walker. "With our project-oriented undergraduate curriculum and our department's emphasis on applied and industrial mathematics and statistics, it will provide many unique opportunities for combining research and education to students at all levels."

DOE funding through C-SAFE supports the researchers, each of whom brings impressive credentials to his work. Walker earned a B.A. in mathematics at Rice University and an M.S. and Ph.D. at New York University's Courant Institute of Mathematical Sciences. Before coming to WPI, he was a faculty member at Texas Tech University, the University of Houston and Utah State University, and held visiting faculty positions at the University of Denver, Cornell University, the University of New Mexico and Yale University.

Sarkis, an expert on numerical algorithms for parallel computing and computa-



tional fluid dynamics, also earned a doctorate at the Courant Institute. He spent four years as a postdoctoral associate at the University of Colorado at Boulder before joining the WPI faculty in 1998. Tocci majored in math at WPI and completed his Ph.D. at North Carolina State University in 1997.

The software and numerical algorithms Walker, Sarkis and Tocci expect to develop may also find applications in other research under way in the Mathematical Sciences Department. In addition, members of the University of Utah's C-SAFE team have begun to formulate strategies for integrating their research results into the undergraduate engineering and science curriculum.

"Courses based on the work of the ASCI team may also be incorporated into the WPI undergraduate curriculum within the next few years," Walker says. "Because of our affiliation with C-SAFE, we would be among a very few American universities to offer this experience. As a department, we're involved in many applications that are really important to the rest of science, engineering and society. We try to seize every opportunity to involve our students in these activities."

Where the Rubber Meets the Road

The United States Air Force is interested in **Robert Lipton.** The low-key mathematical sciences professor isn't being groomed to be a pilot or fly a space mission, but his research is important enough for the Air Force Office of Scientific Research (AFOSR) to have supported it with two grants totaling more than $100,000 since 1996.

In his research, Lipton is studying the effect of the interfaces where the components of composite materials meet. The goal is to see how these interfaces affect the overall structural, electrical and thermal properties of the composite.

In composites, two or more materials are blended or combined to form a distinct product. Examples include steel-belted tires, steel-reinforced concrete, the laminated materials used in modern composite airplane wings, and thermal apparel designed to withstand heat, cold or moisture. Lipton has developed new theoretical methods that can be used to relate the nature of the bonds that form between a material's constituent components and the properties of the resulting composite. He recently gave an invited talk on the effects of interfaces in concrete at the 13th Mechanics Division meeting of the American Society of Civil Engineers.

"Composite materials and their transport properties are central to the design of structures for uses ranging from molecular sieve catalysis to ceramic thermal barrier coatings," says Lipton. "The intent of the research is to provide a rigorous theoretical baseline from which we can derive practical rules of thumb for the design of composite materials."

If Lipton is successful, his work could lead to substantial savings for the Air Force and manufacturers in a number of industries. Scientists and researchers seeking better, stronger or more heat-resistant products would be able to select materials based, in part, on how the bonds between them would affect the physical properties of the finished composite product.

The recent DOD/Air Force contract expands research on interfaces that Lipton has been conducting for several years. In previous studies, he focused on particle- or fiber-reinforced materials used in electronic packaging. The challenge for research and development teams is to create packaging materials that can efficiently transport heat away from electronic devices.

Lipton has developed a mathematically rigorous method to identify particle dimensions and shapes that most effectively reduce the thermal energy dissipated inside a particle-reinforced composite package.

"It's very enjoyable to use mathematics to 'tease out' underlying physical properties that often lie behind simply stated mathematical models," Lipton says.

Lipton earned a B.S. in electrical engineering/computer science at the University of Colorado and M.S. and Ph.D. degrees in mathematics at New York University's Courant Institute of Mathematical Sciences. Prior to joining the WPI faculty in 1990, he was the Charles B. Morrey Assistant Professor of Mathematics at the University of California, Berkeley, a postdoctoral fellow at Cornell University's Mathematical Sciences Institute, and a process engineer at United Technologies in Colorado Springs, Colo.

—BONNIE GELBWASSER

Corrections

There were two errors in "The Year in Review" in the Winter 1999 issue. A photograph identified as Professor James Hermanson was actually of Professor Fabio Ribeiro. Here is the correct photo of Professor Hermanson.

With a Fulbright grant Konstantin Lurie, professor of mathematical sciences, will conduct research in Denmark on spatio-temporal material design. The word "material" was omitted from the story.

Twenty years after its founding, WPI's pioneering graduate program in fire protection engineering continues to define and advance the discipline worldwide.

Taming

PHOTO BY PATRICK O'CONNOR

an Element

Two Decades of Making the World Safe From Fire

BY ALLISON CHISOLM

In an article in the May 1898 issue of the *WPI Journal*, Henry Lucian Phillips, Class of 1893, looked boldly to the new millennium. "It is safe to prophesy that not many years will elapse before scientific colleges will seriously consider [fire protection engineering] and include regular lectures or courses upon it in their curriculum."

Phillips was one of hundreds of WPI graduates through the years who made significant contributions to the field of fire safety before it emerged as a formal academic discipline. That distinguished group included Edward G. Watkins, Class of 1886, who invented one of the first practical time clocks and founded Simplex Time Recorder Co., which was also a pioneer in fire alarm systems; George I. Rockwood, Class of 1888, who taught steam engineering at WPI and founded Rockwood Sprinkler Co.; and Howard G. Freeman '40, head of research and development at Rockwood Sprinkler, where he invented the Watermist spray nozzle that saved thousands of lives on Navy ships during World War II. Today, many more alumni, with degrees in such fields as mechanical and civil engineering, are active as fire protection engineering practitioners.

Although it took a bit longer than Phillips predicted, a select few colleges and universities did begin to "seriously consider" the science and technology of fire in the 20th century. Prominent among them was WPI, which in 1979 established the first graduate program in fire protection engineering in the United States. Blazing a trail in a field that was still in the process of inventing itself, WPI's program set the standard for graduate education in the discipline and built a reputation around the world through the work of its faculty and the accomplishments of its graduates. As it celebrates its 20th birthday, WPI's Center for Firesafety Studies can look back with pride on two decades that have truly helped to define the modern art and science of fire safety.

Kindling a New Flame

Henry Phillips was concerned about fire in 1898 because in his lifetime, major portions of cities like Boston, Chicago, Portland and Seattle had burned to the ground. Fires continued to take a toll on life and property over the decades to follow—so much so, that by the 1960s, the United States held the dubious distinction of having the worst fire safety record in the industrialized world. Alarm bells resounded in Congress, which passed the Fire Research and Safety Act of 1968, and in the White House, where President Richard M. Nixon appointed a National Commission on Fire Prevention and Control in the early 1970s. In its hard-hitting final report, *America Burning*, the commission said, "Appallingly, the richest and most technologically advanced nation in the world leads all the major industrialized countries in per capita deaths and property loss from fire."

(Continued next page)

"The school was experimenting with all kinds of things...and the faculty recognized that FPE was a legitimate technical application that was accepted within and outside WPI."

NEIL NORUM

Top, Robert Fitzgerald and Captain William Metterville at Worcester's Grove Street fire station. Since 1993, the nearby West Auburn station has been manned by a team of FPE graduate students, above, who receive housing in return for their service. The Auburn program was started by Richard Pehrson, right, who received WPI's first doctorate in FPE in May.

NEIL NORUM

The report led to a number of dramatic changes in fire safety in the United States, among them the creation of the United States Fire Administration to support the work of local communities in preventing and mitigating the effects of fire. With the advice and consent of the Senate, President Gerald R. Ford appointed David A. Lucht, a former Ohio fire marshal, to the post of deputy administrator.

In 1978, WPI created the Center for Firesafety Studies. It was the world's first self-sustaining academic department dedicated to bringing together individuals from many disciplines to share their fire safety knowledge and expertise. When WPI President Edmund T. Cranch consented to setting up the center, he insisted on appointing a nationally known leader to head the program. He selected Lucht, who left his Washington post and moved to Massachusetts to serve as vice president of a Boston-area consulting engineering firm while heading WPI's center one day a week. By 1985, the program had grown substantially and Lucht made the transition to full-time status as

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professor and director of the Center for Firesafety Studies.

The original idea for creating a fire safety studies program was a natural outgrowth of the innovative WPI Plan, which required students and professors to get highly involved at the interface between technology and greater social issues. Robert W. Fitzgerald, a structural engineer, designer and professor of civil engineering at WPI, saw the American fire problem as a unique opportunity for student projects. Fitzgerald's interest in fire safety was triggered in the early 1970s when he wrote the section on fire for the manual on multidisaster events put out by the Defense Civil Preparedness Agency (now the Federal Emergency Management Agency). In the process, he got to know government and private-sector fire protection leaders, including a number of WPI alumni.

The WPI Plan, then less than 10 years old, had created a culture receptive to new interdisciplinary programs, particularly those with a recognizable social impact. "The school was experimenting with all kinds of things—exciting new avenues of technology—especially with projects," says Fitzgerald, "and the faculty recognized that FPE was a legitimate technical application that had support within and outside WPI. They began to see that fire safety was more than fire engines and helmets—more than building codes and insurance."

The interdisciplinary nature of exploring fire appealed to many students. More than 40 faculty members advised fire-related projects (many sponsored by the Worcester Fire Department) during the 1970s. It was also during this period that computational modeling began to revolutionize many fields of engineering, enabling engineers to simulate complex systems like fire and to find solutions to problems more efficiently.

The combination of student and faculty interest and expertise and the growing sophistication of the field of fire science led WPI to establish the nation's first master's degree program in fire protection engineering in 1979. Twelve years later, it would launch a first-of-its-kind doctoral program in FPE. (The first doctorate was awarded in May to Richard D. Pehrson of Edina, Minn., who works in the Minnesota State Fire Marshal's office.) "The degree programs grew from the bottom up," Lucht says. "The original faculty came from a number of departments. We also had several practicing professionals from the area who taught part time."

The core group of faculty consisted of Lucht, Fitzgerald and Jonathan Barnett '74, now associate professor of fire protection engineering. Barnett, who had worked in the same engineering firm as Lucht, returned to WPI to pursue a fire-oriented doctorate in mechanical engineering (awarded in 1989) and to serve as assistant director of the Center for Fire Safety Studies. Support staff have also played an important role in the development of the program. Administrative secretary Sandra Williams, a key member of this core group, has been helping the center run efficiently since it admitted its first full-time students.

The job facing Lucht and his faculty in the early days of the program was no less than transforming a good idea into a functioning, flesh-and-blood academic and research program. To begin with, there were no students, no faculty, no textbooks and no courses. "My job was to help pull all those pieces together and to find resources to support the program," Lucht says.

"Dave Lucht brought everything together with a passion—that's been the key to our success," says Fitzgerald. "He inspires trust in people. That trust and esteem are held universally throughout America and the world."

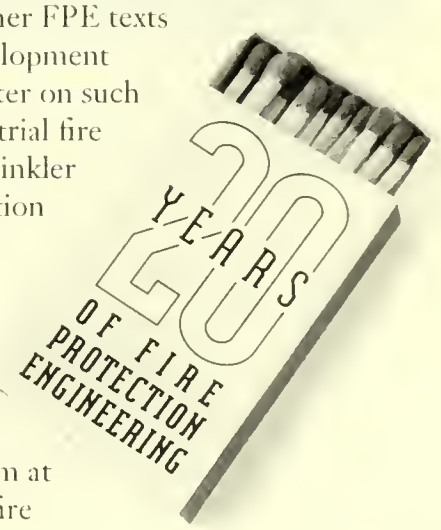
Defining a Discipline

About a dozen students enrolled in the first class—all were part-timers attending classes at night with "borrowed" professors. The first course, Physical Chemistry of Fire, was taught by Edward Cloughery, then chief chemist for the Boston Fire Department. The first full-time students enrolled in 1983. Through the years, nearly half of the students have entered the FPE master's program with a mechanical engineering background. About 35 percent have studied civil engineering and 10 percent have done work in chemical or electrical engineering. The remainder have undergraduate degrees in a wide range of disciplines, including a few in fire protection engineering.

For the young master's program, research, education and technology transfer would be the means to achieving an end that transcended education. "Our goal was more than to offer a degree program," says Lucht. "We were setting out to define a discipline."

In one of the first steps toward that objective, Dougal D. Drysdale was hired to write the world's first advanced textbook on the application of combustion chemistry and physics principles to fire protection. Drysdale is a faculty member at the University of Edinburgh in Scotland, which then offered a master's degree program in fire safety engineering. He spent more than a semester at WPI teaching and writing *Introduction to Fire Dynamics* one chapter per week from his class notes. Published in 1982, the book was recently released in an updated second edition. "It's still the benchmark of the profession," Lucht says.

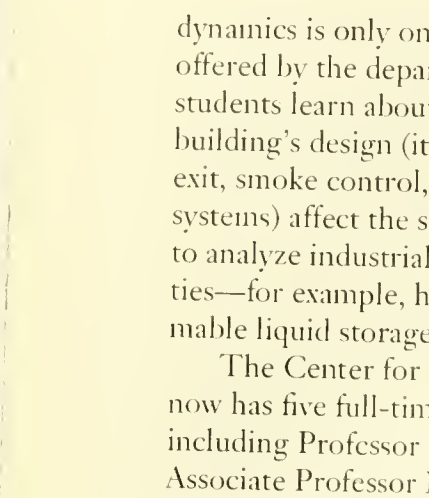
Several other FPE texts are under development within the center on such topics as industrial fire protection, sprinkler systems, detection and alarm systems, and fire chemistry. These texts reflect the breadth of the FPE curriculum at WPI. In fact, fire



dynamics is only one of 17 courses offered by the department. In the others, students learn about such topics as how a building's design (its structure and its exit, smoke control, sprinkler and alarm systems) affect the spread of fire, and how to analyze industrial processes and facilities—for example, how to protect flammable liquid storage tanks.

The Center for Firesafety Studies now has five full-time faculty members, including Professor Robert G. Zalosh and Associate Professor Nicholas A. Dembsey. Zalosh served as an adjunct professor in the early years of the program while doing fire and explosion research at Factory Mutual Research Corp. Since joining the full-time FPE faculty in 1990, he has conducted research on a variety of explosion hazards, including aircraft and tanker ship fuel storage tanks and Compressed Natural Gas (CNG) vehicle fuel systems. He and his research assistants are currently preparing to conduct CNG dispersion tests in the parking garage of the Saltonstall Building in Boston.

Dembsey oversees the center's Fire Science Laboratory. A member of the faculty since 1995, he is currently advising four doctoral candidates. "I like experimentation and engineering applications," he says. His role in the department enables him to work in both areas.



Dembsey's current research ranges from thermal performance of fire protective clothing, to fire performance of marine composite panel systems for fast ferries, to strategies for validating of computer fire models.

The scope of the department has been broadened through the involvement of experts from other disciplines. Management Professor Francis Noonan, who has a joint appointment in fire protection engineering, teaches risk analysis and management. Professors in a number of other academic departments at WPI collaborate with FPE professors on research and projects. They include computer science faculty members David C. Brown and Matthew O. Ward, and mechanical engineering professor Brian J. Savilonis. The department's adjunct faculty members, which include Clougherty and Robert P. Schifiliti '79 ('85 M.S. FPE), president of R.P. Schifiliti Associates Inc., bring a practical fire protection perspective to the center.

That perspective is a critical element of the FPE curriculum at WPI, since the ability to apply engineering science to real fire problems is at the heart of fire protection engineering. The center's faculty and staff recognize that its master's and doctoral candidates are looking toward careers that will enable them to put their knowledge into practice.

Graduate internships are one way the center helps them reach that goal. The internships vary tremendously. Dozens of companies and organizations have sponsored internships for WPI fire protection engineering students, including the National Fire Protection Association, Intel Corporation, the Dallas Fire Department, Westinghouse, IBM, the National Institute of Standards and Technology, 3M, Underwriters Laboratories and the U.S. Navy. One of the most unusual internships took Douglas Carpenter to the bottom of the world, where he evaluated potential fire safety scenarios and protective methods for buildings at the South Pole's McMurdo and Amundsen-Scott stations with funding from the National Science Foundation.

"Our master's is a first professional degree," notes Lucht. "The majority of these students pay their own way and are career-bound. And the jobs pay well—in the vicinity of $50,000 to start. Employers hire our graduates because the technology is changing so fast the world can't keep up. They need to have technical specialists in this field."

Like their counterparts in other engineering disciplines, fire protection engineers are responsible for knowing how to do a variety of tasks. FPE graduates may design sprinkler, alarm and smoke-control systems, perform risk analyses of major industrial facilities, investigate fires and explosions, consult with architects on the design of skyscrapers, hospitals, hotels, sports stadiums and other structures, or do basic or applied research involving fire.

What sets them apart is their passion for their work, says Lucht. "They feel they have a bit of a calling—it's more than just a route to a paycheck." Fitzgerald agrees. "FPEs are a passionate, opinionated, but very congenial group," he says. "But they're also quite willing to share their knowledge and offer help and resources. People in the fire business are different from people in many other technical fields. If you ask them a question, they'll answer it. But then they'll go on and determine what you really wanted to know—and then answer that.

"Like firefighters, they're very giving, very responsive. They like to do good. Their field just happens to be quite profitable. It's a business that, once people get into it, they rarely leave."

A Program With Global Influence and Reach

As graduate programs, the master's and Ph.D. curricula offer opportunities for a strong emphasis on research. Students work with faculty members on a wide range of research initiatives, covering such advanced areas as computer fire modeling, fire performance of structural systems, fire growth and smoke characterization, fire safety design methods and explosion phenomena. Over the years, research in the department has covered a wide range of topics, from fire safe design in Coast Guard and Navy vessels, to the combustion characteristics of materials, to testing the effectiveness of new fire suppression chemicals, to the development of new software tools for modeling fire and predicting fire behavior.

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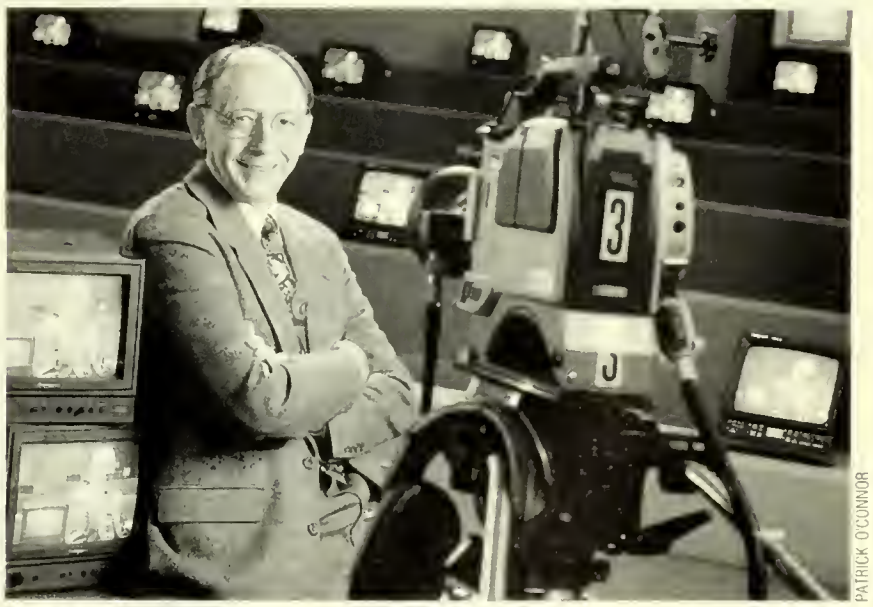
Supporting this active research program is the Computational Fire Modeling Laboratory, equipped with engineering workstations and other tools for high-performance computer modeling. Barnett oversees this lab, which provides students with opportunities to work at the cutting edge of computer applications in fire safety.

The program is also supported by the 2,000-square-foot Fire Science Laboratory, equipped with test apparatus and instrumentation funded by the National Science Foundation and industry. The fire science lab offers state-of-the-art capabilities that include cone and room calorimeters, a smoke density chamber, flame spread apparatus, infrared imaging system, a phase doppler particle analyzer, explosion test vessels, and special smoke detectors, fire pumps and sprinkler system control values. Corporations that wish to undertake small-scale testing of new product materials can also take advantage of the lab's capabilities.

Just as research has helped to enhance the Center for Firesafety Studies' reputation, the tools of distance education have helped bring its curriculum to students around the globe. In 1993, WPI became the first university to offer for-credit courses in fire protection engineering via distance learning. Demand for the University's expertise from the far corners of the world convinced the center to give distance education a try. "People kept telling us, 'We need your program and your information, but we can't quit our jobs and come to Worcester,'" Barnett says. "Through distance education, we've been able to identify a market need and deliver quality courses to practicing professionals throughout the world."

Clockwise from top, graduate student Douglas Carpenter completed an NSF-sponsored internship at the South Pole; Center for Firesafety Studies Director David Lucht in the television studio where the center's distance-learning materials are produced; the LIFT (lateral ignition and flame transport) apparatus in the Fire Science Laboratory; Jonathan Barnett (right) in the Computational Fire Modeling Laboratory.



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VAUGHN WINCHELL

"Fire protection engineers feel they have a calling. It's more than just a route to a paycheck."

VAUGHN WINCHELL

PATRICK O'CONNOR

Above, Nicholas Dembsey, left, and Robert Zalosh observe the operation of the cone calorimeter (also pictured at left) in the 2,000-square-foot Fire Science Laboratory. Below, Sandra Williams, administrative secretary for the Center for Firesafety Studies.

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Students at some 100 locations throughout the United States and Canada, as well as several overseas sites, have taken FPE courses via distance education. Last year, one of Barnett's distance learning courses was delivered simultaneously to students in several locations in the United States and Sweden. Courses have also been offered via teleconferencing at Underwriters Laboratories in Northbrook, Ill., for more than three years.

Lectures are recorded in a studio classroom on videotape, duplicated and shipped within two days to the students; other materials are posted on the Web. Students send in their work electronically and contact their professor and fellow students via e-mail, phone and fax. For group projects, students divide up tasks and work interactively on the Web and through e-mail.

"We've found distance learning to be an effective way to educate adults," notes

Lucht. "Studies have shown that for practicing professionals, the learning quality is as good as or sometimes better than in a classroom. There is a great need out there. Thousands of engineers want to upgrade the skills they've learned on the job. We can reach them at home or at work—wherever UPS delivers."

To complete a master's degree via distance learning, students may fulfil up to one-third of the course requirements by taking appropriate graduate courses at a university near their home or workplace.

The Center for Firesafety Studies also offers four- or five-course distance learning "packages" that enable students to earn a graduate or advanced certificate in fire protection engineering. These credits may be applied toward a master's degree. The first graduate certificate recipient, Marty Pabich, is a senior project engineer for Underwriters Laboratories in Northbrook, Ill. He will continue his work toward a master's degree by combining distance learning and courses at a local university. Tracey Bellamy, a fire protection engineer in Atlanta with a master's in civil engineering, earned the first advanced certificate and has plans to complete a second master's in FPE.

Partnerships and Funding for the Future

Strategic alliances with other universities are in keeping with the Center for Firesafety Studies' mission to "define the discipline and get the information out there," says Lucht, who notes that the program is currently exploring relationships with universities in Thailand, Brazil and Costa Rica. Over time, these alliances may yield new academic and research programs that build on the strengths of each institution. WPI's faculty, its experience in graduate education, and its distance learning resources are among the assets the University brings to these relationships, Lucht says.

Faculty and students in fire protection engineering at WPI have also been active in forging ties with institutions overseas. Fitzgerald has been especially involved, having been appointed a visiting professor of engineering at Pernambuco University in Brazil and an external examiner for the graduate fire safety engineering degree at the University of Ulster in Ireland. He was recently appointed an international visiting fellow at the Fire Service College in Moreton-in-Marsh in England, where he trains instructors in advanced building fire safety evaluation methods. A number of student projects focusing on fire safety have been conducted in New Zealand, Germany and London, among other locations. Barnett recently returned from Melbourne, Australia, where he supervised nine undergraduate students who completed fire-related Interactive Qualifying Projects.

In addition to strategic alliances, financial support will be a key to the future success of the Center for Firesafety Studies.

> "The work of our faculty and alumni around the world is helping advance fire safety and make the world a safer place."

"The uniqueness of our program and its clear benefits to society help us with fund raising," Lucht says. The first donor to the program was the late Percy Bugbee, former general manager of the National Fire Protection Association. A more recent result of Lucht's fund-raising efforts is the Howard W. Emmons Distinguished Scholar Endowment, named for the late emeritus professor from Harvard who is considered the founder of modern computer fire modeling. This fund and several others are used to bring distinguished lecturers to campus. Industry has also been generous, supporting the center with some $3 million in contributions.

Contributions have supported a variety of program needs. They are also enabling the center to build the Fire Protection Engineering Distinguished Scholar Endowment to support the department's teaching faculty, the most critical component of the FPE program, with teaching assistantships, lectureships, professional development stipends and specialized equipment required by faculty in the pursuit of scholarly interests.

"Our program has evolved significantly," says Fitzgerald. "During the first couple of years we developed courses, books, ideas and so on. Until the mid-1980s we were really in an early stage—still adolescents. Now we are reaching maturity in our capabilities, technology and people. In many ways, we're much further along than we thought we would be at this time."

Today, WPI's FPE graduate programs are testimony to the tenacity and hard work of its founding members. More than 100 students are now enrolled in fire protection engineering graduate programs, including eight doctoral students. The Center for Firesafety Studies also offers a five-year B.S./M.S. program for high school graduates and short courses and seminars that help working professionals keep abreast of the field's fast-changing technology. A video-based self-instruction short course is under development.

The field of fire protection engineering also has changed considerably over the past two decades. Deaths from fire in the United States have dropped by some 50 percent since *America Burning* was issued. Computer modeling, new materials and fire-suppression agents, new fire safety technologies, new approaches to design, and new regulatory practices are transforming the way engineers look at fire safety in buildings and vehicles.

"We certainly can't take credit for all these changes," Lucht says, "but the work of our faculty and our alumni around the world is helping to advance fire safety and make the world a safer place. Nearly half of our graduates are employed in the fast-growing field of consulting engineering. The others work for local fire departments, state fire marshal's offices, large industrial companies, government agencies, insurance companies, research and testing labs, building materials, codes and standards organizations, and fire protection systems manufacturers.

"They're at work on five of the seven continents, from Brazil to China. They have changed the way people and structures are protected from the devastation of fire. They are making a difference, and I think that is the most important outcome of these past 20 years."

—Chisolm, a freelance writer in Worcester, writes frequently for the Journal.

Rewriting the Rules Down Under

Performance-based building codes are the wave of the future in the field of fire safety. The future has already arrived in Australia and New Zealand, thanks, in part, to the work of three WPI graduates.

BY ALLISON CHISOLM

PHOTOS BY NEIL NORUM

EDITOR'S NOTE: *In early June, more than 100 architects, engineers, building code and fire department officials, attorneys, insurance executives, building owners, researchers and academics from around the world gathered at WPI to discuss a new way of thinking about fire safety in buildings. Supported by a grant from the National Science Foundation, participants examined the barriers standing in the way of implementing new fire safety design methods in the United States and abroad.*

According to conference chair David A. Lucht, director of WPI's Center for Firesafety Studies, since the turn of the century the usual focus of building design has been to "meet the code," rather than to assure that occupants can escape safely before being overcome by fire and smoke. The alternative is known as the performance-based code approach to design and regulatory practice.

New performance-based model fire safety codes, being developed by such organizations as the International Code Council and the National Fire Protection Association, are expected to be available in the United States by 2000, although a host of technical, social, legal, economic, political and institutional concerns will have to be overcome to ensure a smooth transition to this new paradigm. Those charged with considering and implementing performance-based codes can learn a few lessons from Australia and New Zealand, which were among the first nations in the world to adopt such codes. Among the individuals behind the success stories in those two countries are three WPI graduates. They include Peter Johnson, who spoke about his experience at the recent WPI conference. Here are the stories of these three fire safety pioneers.

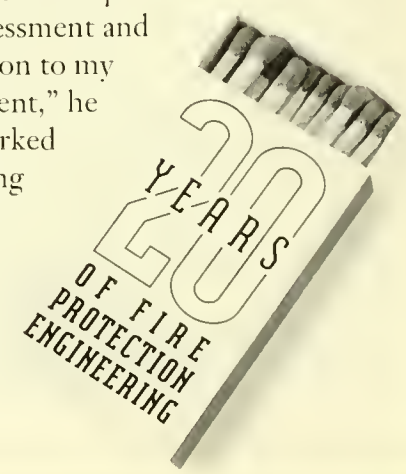
Peter Johnson

There are buildings under construction today in Australia that could not have been built five years ago because they defy traditional building code classifications. They are under way, in part, thanks to the passion of Peter Johnson '86 (M.S.), who helped bring about his country's adoption of performance-based building codes that recognized the value of technological advances in fire safety engineering—advances he learned about while studying at WPI.

Johnson is a principal in the Melbourne office of Ove Arup and Partners, an international consulting firm with 4,000 employees in more than 40 countries. Since joining the company in 1995, he has established and nurtured its fire safety practice, opened new offices in Sydney and Brisbane, and worked on projects around the world, including Tel Aviv's Ben Gurion International Airport, New York's JFK International Airport, the National Gallery of Victoria, the Scottish Gallery of Art and Design, and the Homebush Bay Rail Station in Sydney, site of the 2000 Summer Olympics.

Johnson's determination to revise and unify Australia's building codes has taken him on an interesting journey. By the time he enrolled at WPI in the mid-1980s, he'd earned a bachelor's degree in physics at Monash University in Melbourne and had spent a decade testing fire detection and suppression systems at the government's Scientific Services Laboratory in Melbourne. "I was keen to do further study," he says. "I had seen where fire safety design was going."

After reading a textbook on fire protection engineering that Dougal Drysdale of the University of Edinburgh wrote while he was a visiting professor at WPI, Johnson made plans to study for a master's degree in Scotland. But after that program was discontinued, he came to WPI, instead, to earn his master's. When he returned to his laboratory, he was the only person in his country with an advanced degree in the field. "I could go out and practice risk assessment and fire protection to my heart's content," he says. He worked on everything



from hospitals to computer centers and even evaluated buildings used for scientific research on Australia's bases in Antarctica.

But his education had given him a new perspective on the emerging field of fire safety. "In the past," he says, "fire safety was governed by prescriptive rules. It was a cookbook approach to evaluating buildings. Every state in Australia had its own building codes."

During the past 20 years, however, building construction has seen a slow but steady infiltration of engineering design principles that use computer modeling and complex research to quantify risk and compare alternative design solutions. Johnson became convinced of the value of a nationwide, performance-based building code that would enable architects and engineers to ensure that fire safety features suit a building, instead of fitting the building to a set of code classifications.

"When used appropriately," says Johnson, "performance-based designs result in equal or better levels of fire safety and more functional buildings. They encourage flexibility and innovation and ultimately produce more cost-effective structures." For example, he says, where codes once proscribed how far apart exits must be, they now specify only that the placement of exits must permit the safe evacuation of a building in the event of a fire. "It's up to the engineer to make that decision based on a series of analyses and engineering design methods," he says.

In 1989, Johnson joined a group led by Professor Vaughan Beck, a visiting fellow at the Warren Centre for Advanced Engineering at the University of Sydney. They set out to investigate the use of risk assessment tools and a rational engineering approach to fire safety design of buildings.

The group expanded to include 75 Australian fire safety specialists and several visiting experts. Johnson and six others stayed on to write the Warren Centre's final report, which is considered a landmark in the development of performance-based approaches, internationally. The team of seven stayed together and became major contributors to the Building Regulation Review Task Force convened by the federal and state governments in 1981. The resulting National Building Fire Safety Systems Code is "still regarded worldwide as one of the first attempts to provide a systematic approach to the design of fire safety in buildings," says

NEIL NORUM

"Performance-based designs result in equal or better levels of fire safety and more functional buildings. They encourage flexibility and innovation and ultimately produce more cost-effective structures."
— Peter Johnson

Johnson, who notes that "the draft as it stood was useful to researchers but not for practitioners."

To adapt the code to more practical applications, Beck began offering a fire safety course at Victoria University of Technology; Johnson was involved in course development and lecturing. Some of his lectures were based on the risk assessment methods Johnson had learned from Professor Robert Fitzgerald at WPI. "Fitzgerald foresaw how risk assessment could be a powerful technology to predict rare events with severe consequences," Johnson says.

In 1994, the group, which Johnson says wanted desperately to get beyond the draft stage for their proposed code, founded the Fire Code Reform Center as a not-for-profit facility to manage fire research in Australia. Today the center has a $7.5 million budget and collects funds from government agencies and individual donors and allocates them to key research centers around the country.

During the following year, Johnson served as author, project manager and principal research consultant for a project that led to the center's publication of the Fire Engineering Guidelines, a design guide for fire safety practitioners in the building industry. The center recently underwent an international review, with WPI Adjunct Professor Craig Beyler and master's program alumnus Brian J. Meacham '84,'91 (M.S.), research director at the Society for Fire Protection Engineers, among the reviewers. Johnson reports with justifiable pride that their review of the guidelines characterized it as "a fundamental document, far ahead of anything else in the field, with a major impact on international standards." In fact, Finland has already begun to use it.

"Australia is now at the forefront of building fire safety design," says Johnson. "We're seeing a steady flow of Americans coming over to see how things work here." While he remains modest about his role in changing the face of Australian building regulations, he does acknowledge one important contributor to his success. "All of this I owe to WPI," he says. "If I hadn't enrolled there for my master's degree in fire protection engineering, I might still be testing fire detectors."

Alison Wakelin

Growing up in Auckland, New Zealand, Alison Wakelin always wanted to live overseas and do further study. With the opportunity to come to WPI, she realized it would be possible to combine those goals.

After three semesters in Worcester, she earned a master's degree in fire protection engineering in 1997. Her graduate studies were funded by her employer, Holmes Consulting Group, and by a national fellowship for young civil engineers.

Wakelin studied civil engineering in college and worked as a structural engineer. She learned about fire protection engineering from a senior colleague. The field appealed to her particularly because in 1993, New Zealand became one of the first countries in the world to implement a performance-based building code. "The new code makes our jobs more intellectually stimulating," she says. "There can be significant benefits by not being constrained by rigid rules."

To further her career, however, Wakelin knew she needed additional

ALISON CHISOLM

"The new (New Zealand performance-based building) code makes our jobs more intellectually stimulating. There can be significant benefits by not being constrained by rigid rules."
— Alison Wakelin

training. She selected WPI because she believed it had the best and best-known program. Her stay in Worcester dismantled many of her misperceptions about America. She found that the United States was not covered by highways and parking lots, that Americans eat fresh fruits and vegetables—as well as junk food—and that the country has a lot of uncultivated land. (New Zealand, whose landmass is slightly smaller than that of Colorado, contains far more rolling pasture than the hills of New England.)

It took her nearly a year to adapt to American culture, but as graduation approached she found she didn't want to go home. She did, though, because "many people had shown faith in getting me to Worcester and I owed them the courtesy of coming back."

Wakelin also felt obligated to share the benefit of what she'd learned—her time at WPI had opened her eyes to new approaches in her field. But, she says, she found few companies undertaking the type of industrial construction that would enable her to practice the new technologies and techniques she'd learned.

In October 1998, Wakelin moved back to the United States and began a new job with Hughes Associates Inc. in Baltimore. "The company is more research-based," she explains, "with projects of a national scope. It has its own lab, which my former employer in Auckland didn't have."

Wakelin continues to reflect on her time at WPI, particularly as challenges come up at work. "I got a lot out of going to WPI," she says, "that I wouldn't have gotten anywhere else."

Colleen Wade

Colleen Wade '96 (M.S.) didn't want to be just another architect or engineer. While interested in the building industry, she says, "I've always liked to do things a bit differently."

In her last year of a two-year building science honors program, the New Zealand native took a course on fire in buildings that made her realize there was more science in the field than she had believed. Her final research project was on principles of smoke movement in buildings.

Young engineers realize quickly they need a specialization, and Wade found fire was a good way to set her apart from her peers. She also realized she needed further study, but there weren't many fire programs at the graduate level. "WPI seemed to pop out," she says. "It was considered to have the best program, a good reputation and a good faculty."

Wade spent the 1994-95 academic year in Worcester, taking a full course load. "It was very intensive," she recalls, "but I didn't mind that at all. It was an enjoyable challenge." Her employer, the Building Research Association of New Zealand (BRANZ), paid her tuition and major expenses. She completed her thesis project in Wellington, staying in touch with her advisor, Jonathan Barnett, associate professor of fire protection engineering, via e-mail. Her research, a project for BRANZ, was a room fire model incorporating fire growth in combustible lining materials.

Fire protection engineering is different from other disciplines, Wade says. It draws from many other areas, such as heat transfer, fluid dynamics and building structure materials. "And there's always an opportunity to apply research to practical projects."

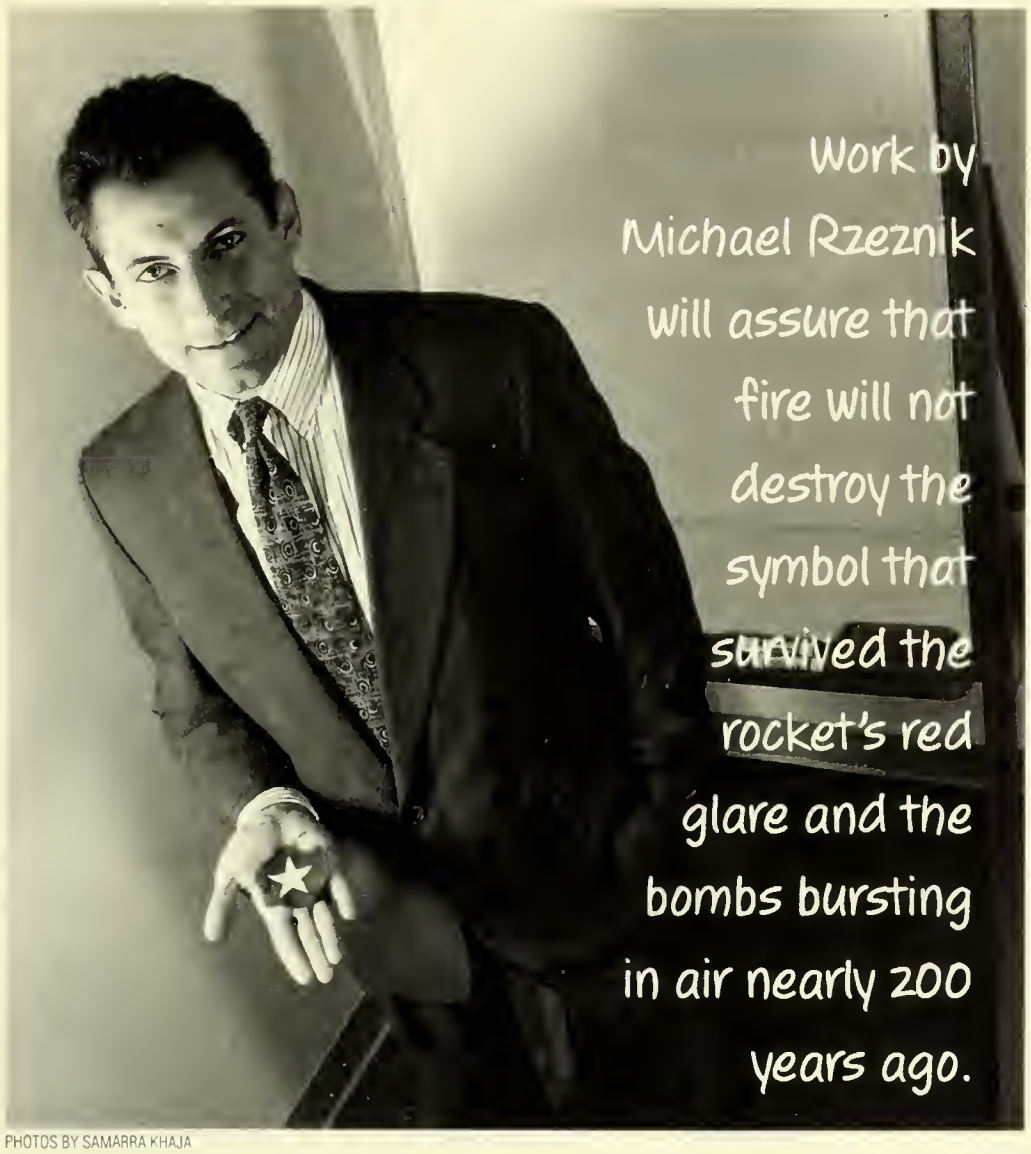
That's especially true in New Zealand, where a performance-based building code requires fire protection engineers to demonstrate a building's compliance with current codes, even if it doesn't strictly meet all its requirements. "The building code has a prescriptive solution," she says, "and a performance-based design permits you to make changes where the requirements are excessive or unreasonable, or when the architect has different ideas."

Wade worked in fire research with BRANZ for 11 years before joining Connell Wagner Ltd. in Wellington. She recently returned to BRANZ. Since coming home to New Zealand, she has helped review fire-related aspects of the country's building code, which, she says, presents "another avenue for getting research results into practice." She's also participated in the peer review of the design for Wellington's new national museum, Te Papa. The building's design, which includes several large atria and floors that open to each other, presented a challenge to the fire protection engineers (Fire Risk Consultants Ltd.) regarding smoke spread and evacuation times. A computer simulation helped determine the best escape routes and demonstrated the effectiveness of using fans to blow air into some of the building's protected escape routes to clear away smoke.

Now that fellow New Zealander Alison Wakelin has returned to the United States, Wade is one of just five female fire protection engineers in her country. (In earlier years, she was the only woman working in fire protection engineering in New Zealand.) That distinction doesn't concern her much. She'd rather be known for her specialization in fire protection. As she says, "I've just got on and done the job."

One of the more interesting assignments Colleen Wade has undertaken in her home country is the peer review of Te Papa, New Zealand's new national museum.

Protecting a Grand Old Flag



PHOTOS BY SAMARRA KHAJA

BY RAY BERT '93

Early on the morning of Sept. 14, 1814, American soldiers defending Baltimore's Fort McHenry from the British ran an enormous flag up the fort's 90-foot flagpole. "As the last vessel spread her canvas to the wind, the Americans hoisted a most superb and splendid ensign on their battery," wrote an English midshipman. Eloquent though they were, his words are far from the most famous inspired by the raising of that flag, which had been made by a local seamstress for the princely sum of $405.90.

Originally commissioned in 1813 by Lt. Col. George Armistead, the fort's commander, the 35-foot by 42-foot Star-Spangled Banner flew over the garrison during a heavy bombardment by British ships at the height of the War of 1812. Francis Scott Key, a Washington lawyer detained aboard a British ship in the Baltimore harbor, watched the assault from afar. When Key saw—by the dawn's early light—the huge flag flapping defiantly over the fort as the British retreated, signaling that the fort, and most probably the country, had survived, he was inspired and penned a poem that he originally titled "The Defense of Fort McHenry." In time, the popular verse was set to music and, in 1931, was officially designated America's national anthem.

Until sometime in 2002, visitors to the Smithsonian's National Museum of American History can watch as one of America's most significant national artifacts undergoes a delicate, $18 million preservation operation. Patrons will see the 1,020-square-foot Star-Spangled Banner—the actual flag immortalized by Key—laid out on an enormous "operating table" in a specially designed laboratory. They will see a team of eight conservators, as exacting and careful as surgeons, shuttling just above the flag on a gantry system, cleaning and treating the 187-year-old "patient." They will see the scars of the War of 1812 and the 15 stars (one for every state in the still-young nation), reminders of America's early days.

What they won't see, and will probably never hear about, is a high-tech system hidden behind beams, around corners, and in the placement of the doors and passageways of the laboratory—a system that will only be put to the test if catastrophe strikes. They won't see the ultrasensitive aspirating smoke detection system or the suppression system capable of quickly extinguishing a fire with little or no damage to the fragile flag. They won't see any of that, because WPI graduate Michael J. Rzeznik designed it that way.

When Rzeznik, a senior fire protection engineer with Gage-Babcock & Associates who earned his master's degree in fire protection engineering at WPI in 1994, was first assigned to protect the nearly 200-year-old flag, it seemed like a routine task. "I didn't understand the significance of what I was going to be protecting," he says. "I figured it would take all of 15 minutes."

He soon found out otherwise. What he originally thought of as "just a flag" is considered one of the

three most important U.S. historical artifacts, the others being the Declaration of Independence and the Constitution. The Smithsonian hired Gage-Babcock in the summer of 1997 to design a system that would protect the flag from fire during the three-year conservation process—a system that might be reconfigured for use in the new, climate-controlled display case where the flag will eventually take up permanent residence.

Rzeznik, who managed the Star-Spangled Banner assignment for the company, began work on the project during the summer of 1997 and completed most of the design between November and the following April. He did nearly all of the engineering himself, he says, because, although it was very sensitive work, it wasn't a voluminous fire protection scheme. But he notes that working with American History Museum conservators (who have an intensely personal connection to the flag and its safety) made the project both more satisfying and more challenging.

"In [fire protection], often clients bring you on board as a result of federal, state or municipal regulations or requests," Rzeznik says. "People usually aren't too excited about the issues. It's a lot easier to get across the importance of doing things right when people really care, as they did in this case." But that increased caring came at a cost: Rzeznik spent considerable time carefully assuaging concerns about the potential dangers to the flag, and learning in the process just how important this "15-minute job" actually was.

Serving as a prominent engineering firm's point man for arguably the most historically significant recent project of its kind was not what Rzeznik imagined himself doing as he worked toward a bachelor's degree in physics at the State University of New York at Albany in 1989. In fact, he got into the fire protection field by accident. "I was always told, 'study what you enjoy,' and I liked physics," he says. "I didn't have any real idea in mind of what I would do with it." Before he had completed his junior year, he already knew he didn't want to teach high school or go on to earn a Ph.D. in physics. About that time, his father read an article in *Omni* magazine that listed fire protection engineering as one of the hottest new careers—one with numerous jobs and good pay.

Rzeznik did some research and found that WPI was the only university offering advanced degrees in the field at that time. That spring, he talked with David Lucht, director of WPI's Center for Firesafety Studies, who so impressed him that he enrolled in the center's master's degree program. Lucht, whom Rzeznik calls "a great ambassador for the industry and for WPI," also proved something of a savior. "At the end of 1989, I was broke and had to get a job," Rzeznik says. After Lucht noticed him scanning job listings in the department office one day, he and former professor Richard Custer helped set him up with a paid internship at Rolf Jensen Associates in New Jersey. "That internship made it possible for me to continue my studies."

Rzeznik says he developed a great deal of respect for the entire FPE faculty at WPI, especially Robert Zalosh, who advised his thesis on the atmospheric dispersion of combustion products from large tire fires. "Professor Zalosh was the most demanding professor I've ever had," he says. "I learned a lot working with him."

Rzeznik says WPI's strong presence in the field of fire protection engineering has helped him network through the highly specialized, tightly knit FPE profession. "When I meet someone new in the industry, chances are I know someone he knows," he says. And not infrequently, the people he has encountered in his career have direct ties to the University.

His internship with Rolf Jensen, a company founded by a member of WPI's Fire Protection Engineering Advisory Board, led to a full-time position in 1992. He remained at Jensen as he finished his thesis and collected his master's degree in 1994. In 1996 he joined the Harrington Group in Atlanta, a fire protection consulting firm founded and run by Jeffrey Harrington '77, and where Jim Russo '92 is vice president. Among the projects he completed for Harrington was an evaluation of the smoke-control system in CNN Center.

He joined Gage-Babcock in Fairfax, Va., the following year and soon had another fortuitous alumni encounter as he began designing the fire suppression system for the Star-Spangled Banner. The criteria he specified for nozzle discharge pressure for the suppressant agent was tight: 70-75 psi. This limited range was selected to ensure that suppression would be rapid enough to protect the flag from fire damage, while avoiding damage to the flag from the force of the discharge. The contractor said he couldn't meet such tight tolerances.

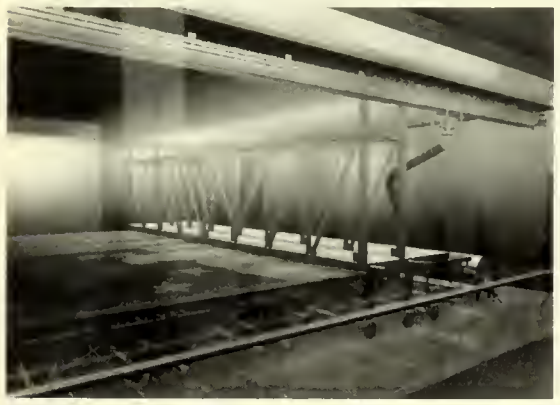
An engineer from Kidde Fenwal, the system vendor, was brought in. When Rzeznik found out the engineer was Kevin Richards '87, he knew reaching an agreement would be much easier. "I was confident that he was qualified because I knew where he went to school," Rzeznik says. The camaraderie and common ground helped, and they won the battle, working to the tight specs. Yet another WPI alumnus, Andrew Bowman '94 (M.S.), also with Gage-Babcock, was involved in acceptance testing of Rzeznik's design.

Rzeznik with some of the tools of his trade. Opposite, a rendering of the chamber where the Star-Spangled Banner will be restored and a diagram of a sampling port that will draw air into the aspirating smoke detection system Rzeznik designed.

The 187-year-old Star-Spangled Banner is exceedingly fragile; the fibers making up its 15 still-broad woolen stripes and 15 no-longer-bright cotton stars have grown brittle with age and exposure to oxygen and light. The painstaking work to be carried out by the conservators—believed to be the single

largest textile conservation effort ever undertaken by a museum—required a system that would virtually eliminate the possibility of a catastrophic fire. For such an irreplaceable item, particularly one that will burn as easily as newspaper, "virtually any fire would be considered a catastrophe," Rzeznik notes.

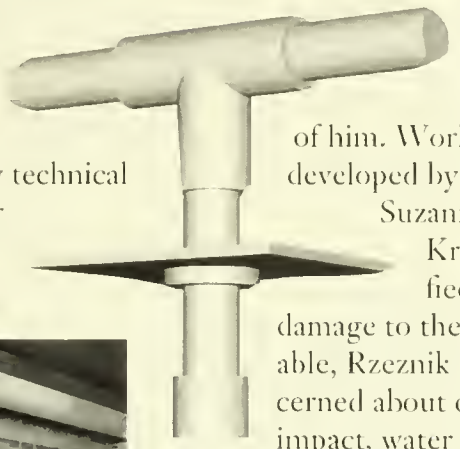
Spencer Crew, director of the Museum of American History, calls the Star-Spangled Banner "America's single most important icon" and describes the preservation as "complex, highly technical work." Simply taking the banner down from its display area in Flag Hall was an engineering



challenge, as handlers used an opaque, tear-resistant, nonabrasive fabric called polyolefin to protect the flag from light, dust and moisture damage; a specially designed suspension system supported the flag and its reinforced aluminum frame from top to bottom as it was lowered.

The flag wasn't always treated so delicately. The Armistead family, which acquired the flag after the war, gave away one of the stars and several swatches as souvenirs, reducing the flag's length to 34 feet. The Smithsonian eventually acquired the national treasure in 1912. Early conservation efforts were, by today's standards, decidedly low-tech, including vacuuming and spot-cleaning it with gasoline. In 1914, a team of seamstresses sewed on a linen backing (requiring more than 1.7 million stitches) in an attempt to keep the flag together. In 1984, two years after an extensive surface cleaning, the flag was covered with an opaque screen to protect it from light and dirt. The screen, which was lowered for five minutes each hour for the playing of the national anthem, was not effective in keeping out lint and debris, and has not been in use since 1994, when supporting cables broke.

Conservators are still evaluating the flag and determining exactly what will comprise the newest and most extensive conservation effort. The linen backing may be removed, or the stitching may be dyed to match the flag's present color. The surface will certainly be cleaned again, prior to installing the flag in the huge climate-controlled display case.



Unlike the conservators, Rzeznik had a clear idea of the job that lay ahead of him. Working under criteria developed by Chief Conservator Suzanne Thomassen-Krauss, which specified that no level of damage to the flag was acceptable, Rzeznik had to be concerned about damage from impact, water and chemicals as he determined how best to prevent, detect and suppress a fire in the lab area.

For prevention, he all but banished electrical equipment in the lab and separated the structure from the rest of the museum with noncombustible partitions to keep smoke from fires that might start outside the lab from getting in. Another set of barriers, including a fire-resistance partition and smoke and fire dampers in duct work, separate the lab from an adjacent support area where flammable and combustible liquids used in dyeing and cleaning operations will be stored.

The laboratory's aspirating detection system is a crucial element in limiting damage to the flag. The system draws lab air through PVC tubes into a central unit, where it passes through a laser. Smoke particles in the air interrupt the beam, triggering alarms and automatic response sequences that vary depending upon the concentration of smoke. This system will be adapted for use in the final display case.

By far the most difficult part of the job was selecting the most appropriate suppression system, and then convincing the conservators that it was the best choice. "It quickly became evident that a sprinkler system would be too slow," Rzeznik says. Even if sprinklers were capable of extinguishing a fire quickly enough, the water could cause irreparable damage. Rzeznik decided on a gaseous agent, which left him with a choice of two categories of "clean agent" gases: inert and halocarbon.

Inert agents extinguish fires by displacing oxygen. To halt a fire before it could cause appreciable harm, large volumes of inert gas would have to be discharged quickly, requiring high discharge pressures—a minimum of 325 psi, more than enough to seriously damage the flag. Halocarbons are more efficient suppressants, and can be dispensed at lower pressures. But at high temperatures, they can also produce small quantities of hydrofluoric acid. Though the amounts would be negligible, particularly if the fire were quickly controlled, Rzeznik felt obliged to communicate the possibility to the conservators. Not surprisingly, the possibility of acid contacting irreplaceable fabric was a cause for concern.

Rzeznik says there were times he thought concern over the acid might lead the conservators to rely only on the existing sprinkler system, despite his recommendation to the contrary. But with support from one of the Smithsonian's own fire protection engineers, Rzeznik convinced museum personnel that the existing sprinkler system "would protect the building, but not the flag."

With his work on the Star-Spangled Banner now complete, Rzeznik is working in Gage-Babcock's Armonk, N.Y., office, returning occasionally to the D.C. area to check on progress and attend to details. As is typical for fire protection projects, though, the task that was important enough to require his expertise has only just begun. And, if all goes well, the client will never get to evaluate Rzeznik's meticulous work.

"I asked everyone in the office—from the president to the newest engineer—to find a weak link in my design," he says. But the reality is that "we design systems that we hope never have to be used, and that statistically won't ever have to be used." If they are used, flawless performance is expected, while a failure is sure to be high-profile. Like a referee or an umpire, fire protection engineers often have to live with anonymity as the reward for a job well done.

Still, Rzeznik clearly enjoyed the historic context of the flag project. "I don't know when I'll get another opportunity to work on something as historically significant as this. On the other hand, Gage-Babcock & Associates was recently awarded the contract to protect the National Archives Building, home of the Declaration of Independence, the Constitution and the Bill of Rights, so it may happen sooner than I think!"

—Bert, an associate editor at ASEE Prism *magazine, is a frequent contributor to the* WPI Journal.

THE 21ST CENTURY PHARMACY:
CREATING TOMORROW'S THERAPIES

Zeroing In on a Killer

Under the direction of Christopher Sotak, WPI has become a world leader in the use of magnetic resonance imaging to study stroke and cancer and to evaluate new treatments for these deadly diseases.

BY MICHAEL W. DORSEY

In the blink of an eye, a small blood clot breaks loose from the aorta of a 62-year-old man and tumbles into an artery in his neck. Approaching the brain, it is whisked into a smaller artery and quickly lodges in the narrowing vessel, blocking the flow of blood to a section of cerebral cortex about the size of a tennis ball.

Deprived of oxygen and nutrients, the brain cells nearest the artery anaerobically burn their small stores of glucose, releasing telltale traces of lactic acid. Then they starve. Without energy, the sodium pumps in their membranes shut down, letting sodium rush in, followed by water. As the cells balloon, they squeeze together, restricting the movement of water in the intercellular spaces.

The damaged cells release toxins, including glutamate that lets calcium flow freely across the membranes like an invading army. The calcium initiates a cascade of biochemical events that eventually kills the cells. Slowly, this sequence of deprivation, biochemical mayhem and death moves like a shock wave through the affected brain cells as the man becomes one of more than 700,000 people in the United States who will suffer a stroke this year.

Only recently has it been possible to see in such detail how stroke affects the brain. This new window on one of the nation's deadliest diseases has been opened by a remarkable medical diagnostic technique called magnetic resonance imaging (MRI), which uses a combination of a strong magnetic field and radio waves to probe the body. Over the past decade, a handful of researchers have found new ways to use MRI to study how killers like stroke and cancer work, to see their effects on the body with stunning clarity, and to evaluate the effectiveness of new medications and therapies. Among these pioneers is Christopher H. Sotak, professor of biomedical engineering at WPI and newly named chairman of the Biomedical Engineering Department.

Since coming to WPI in 1988 to direct the MRI laboratory and research program that WPI operates jointly with the University of Massachusetts, Worcester, he has developed an intimate understanding of the technology and capabilities of MRI. He has put that knowledge to use to develop innovative methods that he has applied in a host of ways, from studying new treatments for tumors to creating new ways of probing systems as diverse as oil wells and tendons. The work has won him a number of awards and honors, including the Established Investigator Award from the American Heart Association and WPI's own Board of Trustees' Award for Outstanding Research and Creative Scholarship. It has also brought international recognition to WPI. Within the past decade, more than 10 visiting medical scientists from around the globe have collaborated on studies with Sotak and his team.

Much of that recognition has come from pioneering studies of stroke and of the effectiveness of pharmaceutical agents for treating stroke and its aftereffects. Working closely with Dr. Marc Fisher at UMass Memorial Hospital, Sotak and several graduate students have turned the WPI/UMass MRI lab into one of the global leaders in the use of the technology to evaluate stroke treatments. They have tested more new drugs than any other laboratory in the world and have produced more than 55 peer-reviewed articles in scientific journals and more than 130 presentations at conferences. The work has been supported by more than $2.5 million in grants and other funding from the American Heart Association, the National Institutes of Health, the National Science Foundation, major pharmaceutical companies and other organizations.

Sotak traces his involvement with MRI to the days before the first human scanners were marketed in the early 1980s. The clinical devices were based on nuclear magnetic resonance imaging (NMR) instruments that have long been used in chemistry labs to study the structure of organic molecules. In the late 1970s, a number of researchers, including Lawrence A. Minkoff '69, now president of M.R. Labs Inc. in Locust Valley, N.Y., found ways to scale the technology up to probe bodies instead of molecules.

While working toward his Ph.D. in chemistry at Syracuse University, Sotak used a large-bore chemistry NMR instrument to study metabolism in perfused rat hearts. After receiving his doctorate, he joined a company that was designing one of the earliest MRI instruments made specifically for animal research. Just before Sotak started work, the company was acquired by General Electric, a manufacturer of human clinical MRI instruments, and Sotak became a software engineer working on the design of the $650,000 device that now occupies about a quarter of his 1,600-square-foot laboratory at WPI.

After two years of writing software, he became an applications scientist, a job that was part salesman and part researcher. He demonstrated the instrument to potential customers, mostly physicians and scientists at teaching hospitals and universities. He also traveled to sites where the instruments had been installed and helped researchers get their experiments to run properly on the complicated devices. Finally, to demonstrate what the devices could do, he conducted original research. "Nearly everything I did then was breaking new ground and was

A self-described "methods person," Christopher Sotak enjoys finding innovative applications for this MRI research instrument.

BRUCE CRAMER

publishable," he says. "It was very exciting. It was the first time that I came up with some experiments of my own. I realized that I probably knew enough about MRI to be an academic."

His chance to join the academic world came in 1988. One of GE's research instruments was sold to the UMass Medical Center and was installed in a laboratory at the Central Massachusetts Magnetic Imaging Center, a clinical MRI facility operated by several area hospitals at the nearby Massachusetts Biotechnology Research Park. The UMass Department of Radiology entered into an agreement with WPI to operate a collaborative research program in MRI, with UMass providing the research instrument and WPI providing a director for the research center.

On a visit to the new laboratory, Sotak learned that the post of center director (a position that also included an appointment as assistant professor of biomedical engineering at WPI) was vacant. He says his growing reputation in the young MRI field and his established research program helped him land the job. At WPI, Sotak continued some of the work he had started at GE. One such project focused on the development of new methods for studying the effectiveness of cancer-killing drugs.

How effective radiation treatments are in destroying cancer cells depends, to a large extent, on how much oxygen those cells receive. Radiation and many chemotherapy agents work best when the cells are well oxygenated, but the rapid growth of tumors often outpaces the growth of blood vessels, leaving cells in the center of a tumor too far from the blood supply to receive adequate oxygen. These hypoxic, or oxygen-starved, cells can be missed by cancer killers, only to become seeds for renewed outbreaks of cancers after the treatment ends. To overcome this problem, radiation is often administered in stages so that cells that are not killed by one dose will be caught by later doses, after oxygen has found its way to them.

Currently, physicians use their experience and judgement in planning the course of radiation treatments. Sotak would like to provide them a tool that would take some of the guesswork out of the process. The tool is based on a group of chemicals called perfluorinated hydrocarbons (perfluorocarbons). When injected into the body, these compounds are captured by macrophages, tiny cells that congregate in areas of infection and in tumors. Perfluorocarbons make tumor cells stand out in MRI images, but they also have measurable properties that are directly proportional to the amount of oxygen in the tissue surrounding them. By measuring the perfluorocarbon signal from the treated tumor cells before and after radiation treatments, physicians may one day be able to carefully adjust the timing of their treatments to achieve the optimal destruction of cancer cells.

> "Nearly everything I did then was breaking new ground and was publishable. It was very exciting.... I realized that I probably knew enough about MRI to be an academic."

Like other kinds of cells, tumor cells deprived of oxygen must metabolize glucose anaerobically, which generates lactic acid as a by-product. "This is what happens if you exercise and you're not in shape," Sotak says. "There's not enough oxygen to meet the demands that you're placing on your muscle tissue, but your muscles don't stop. Instead, they go into anaerobic glycolosis and produce lactic acid as a by-product. It's the lactic acid that makes your muscles hurt."

While at GE, Sotak earned two patents for new techniques he developed to selectively locate lactic acid using NMR spectroscopy. The research was made possible, in part, by newly developed gradient coils that greatly increased the sensitivity of the GE machines. "One of the advantages of working for a company is that you have access to technology that doesn't yet exist

in the academic environment," he says. "That gives you an incredible competitive advantage. You can do experiments that no one else can do."

Once at WPI, he secured equipment grants that enabled him to install the same gradient coils on the machine there. He then continued his research aimed at using lactic acid imaging to map tumors and to evaluate the effectiveness of chemicals called adjuvants, which increase the flow of oxygen to hypoxic cancer cells, making them more susceptible to radiation and chemical treatments.

Sotak says it became clear early on that lactic acid imaging could also be an effective method for spotting cells damaged or compromised by strokes. Lactic acid released by oxygen-starved brain cells can be detected by Sotak's imaging techniques. But before he could design experiments to more fully develop this diagnostic technique, his interest in stroke would take a quite different course.

In 1990, Sotak began collaborating with Marc Fisher, then of the Medical Center of Central Massachusetts, now chief of neurology at UMass Memorial Health Care and professor of neurology and radiology at the UMass Medical School. A team, which also included scientists from Japan and UMass, set out to develop new, more accurate and useful methods for visualizing the progress of stroke and evaluating potential treatments.

When the research project began, doctors had no tools that would enable them to clearly see which sections of the brain were being damaged or killed by a stroke, or how extensive the damage was. Even worse, there were no treatments for the disorder, which is the third leading cause of death in the United States and the leading cause of adult disability. It would be another six years before the FDA approved the first emergency stroke treatment, the clot-busting drug TPA (tissue plasminogen activator). Sotak's work with MRI would help overcome both of those shortcomings.

Sotak's laboratory was one of the first to use a type of MRI called diffusion-weighted imaging to look at stroke damage. The technique focuses not at the brain cells themselves, but at the movement of water molecules within and between them. The diffusion coefficient of water, a measure of the speed of water movement in tissue, has proven to be a highly sensitive indicator of ischemia, the condition caused by obstruction of blood flow to the brain. Within the first few hours after the onset of stroke, brain cells are compromised and the diffusion coefficient in their vicinity declines. The change is probably due to the swelling of injured cells, which makes it more difficult for water molecules to move freely.

In his studies, Sotak augmented diffusion-weighted imaging with perfusion-weighted imaging, which provides a measure of how much blood is flowing through tissue. Perfusion imaging produces a picture of all tissue that is in danger of serious damage, some of which might be saved with prompt treatment. Diffusion imaging shows the tissue that is probably irreversibly damaged. When combined, the techniques create a striking portrait of the progress of a stroke and insight into how to best treat it. Unlike x-rays or CAT scans, which can fail to detect the damage from stroke even many hours after it begins, MRI can provide useful information within minutes of the obstruction of blood flow.

"Everything we've developed is directly applicable to clinical use," says Sotak, who notes that many MRI instruments in hospitals and clinics are now capable of performing perfusion and diffusion imaging. Some of these machines are now being used in clinical trials of new stroke drugs.

"In practice, clinical machines are not as sophisticated as the research machines, and they don't need to be," Sotak says. "In an emergency, physicians need to get a visual estimate of the damage. They need to be able to quickly compare the area shown in the diffusion and perfusion images, because the difference is potentially salvageable tissue. After treatment, physicians want to see if the size of the lesion has been reduced. This is not as accurate a measure as we make with our machine, but it is a great deal more information than physicians had even two years ago for making therapeutic decisions."

Working with graduate students in his laboratory, Sotak spends part of his time refining the perfusion and diffusion imaging methods to increase their sensitivity. Another large chunk of time is spent evaluating potential new treatments for stroke. Over the past decade, the laboratory has become one of the world's leading centers for MRI studies on stroke drugs.

Nearly every new medication introduced to treat stroke—developed by drug companies large and small—has come to the lab; in fact, Sotak's team has evaluated far more drugs than any other lab in the world. They include a number of medications that are now in clinical trials, as well as several others that are still wending their way through the long and costly path to FDA approval. Based on WPI's capabilities in MRI research, AstraZeneca Pharmaceutical Corp. recently awarded WPI a three-year, $530,000 grant to use MRI to evaluate new therapeutic interventions. "It looks like this could turn into a long-term relationship," Sotak says.

"This laboratory is one of the few (if not the only one) in the United States with a research MRI instrument that is fully dedicated to undergraduate, graduate and postdoctoral research and education in biomedical engineering."

Drugs for stroke generally fall into three categories. The first are agents that dissolve blood clots, restoring the flow of life-giving oxygen to brain cells. TPA is the only clot-buster currently approved for stroke treatment, but a number of others are in development. The next group, neuroprotective agents, shield surviving nerve cells from chemical changes that can lead to cell death. Many block the rush of calcium into weakened cells. The third group attempt to counteract the damage that can be done as blood rushes back into ischemic tissue, something known as reperfusion injury.

"In humans, the window for successfully treating stroke is potentially large. It may be possible to save affected brain cells perhaps six to eight hours after a stroke," Sotak says. "In practice, though, you can only administer clot dissolvers during the first three hours after the onset of stroke because the risk of death from reperfusion injury becomes too great after that. As fresh, oxygenated blood flows into tissue that is highly ischemic, it will generate oxygen free-radicals that attack the blood vessel walls, causing them to burst. In this case, mortality from reperfusion injury is potentially greater than the death rate from stroke alone in patients who receive no treatment at all."

In some ways," Sotak says, "our work on stroke drugs has become routine. Our methods are well established, though we continue to refine them all the time. Still, this work helps support the lab and enables us to get into new areas of cutting-edge research." One of those new areas may have startling implications for the course of stroke research and treatment.

"In our previous research," Sotak says, "we had done studies in which we occluded blood flow to the brain for 25 to 30 minutes and then restored it. When you stop the flow, you see a change with diffusion-weighted imaging that appears to be completely reversed once the blood returns. We had always assumed that the affected tissue completely recovers, but in more recent studies we've found out that this is not true."

When Sotak and his team of graduate researchers looked at the same brains one to two days later, they were in for a surprise. Tissue that had looked normal an hour after the restoration of blood flow now appeared injured, and the injury intensified with time. It is thought that the initial insult triggers a genetic change in brain cells that sets off a phenomenon known as apoptosis, or programmed cell death. The apoptotic process is a sort of biological clock that leads cells to commit suicide after a certain period of time. (Sotak says this theory is somewhat controversial, and some scientists believe that the delayed injury in brain cells may be the result of damage to the cells' mitochondria—the organelles that generate energy to keep the cells alive.)

If ischemia can set off apoptosis, then drugs being developed for stroke today may have to be augmented by medications that target the biological events responsible for cell death. "Today's drugs are designed to address the metabolic effects of an interruption of blood flow," Sotak says. "There is a complex metabolic pathway, and each drug interrupts it at a particular point to arrest or even reverse the damage. But the mechanistic pathway in a genetic process would be completely different. The effects of these drugs may prove to be temporary, as the genetic process eventually dominates the whole process."

Sotak says this work may lead researchers to take a closer look at the long-term consequences of another medical condition called transient ischemic attacks. "These are temporary reductions in blood flow in the brain that may be caused by blood clots that spontaneously dissolve. It's now thought that these events are not harmful in and of themselves, but if they are actually triggering programmed cell death, they may have more serious consequences."

Over the past several years, the intensity of the research on stroke pushed some other research areas into the background—including research on the imaging of tumors. But that work is beginning to return to the forefront as more recent studies have revealed that the same diffusion MRI techniques perfected for stroke studies may be highly effective in monitoring changes in tumors. "It turns out that when you treat a tumor, the diffusion coefficient changes by a factor of two—in other words, you get a 100 percent change, which for MRI is spectacular."

A recently completed Ph.D. dissertation by Michael Mgiler used diffusion-weighted MRI to evaluate the effectiveness of the cancer drug 5-fluorouracil. The techniques made it possible to see, with exceptional spatial resolution, which sections of a tumor were killed after a treatment and which sections contained hot spots of living cells. The same techniques could be used in clinical MRI instruments to monitor how well patients respond to treatment. "Because it's now required for stroke interventions, diffusion-weighted imaging has been added to many clinical instruments," Sotak says. "This now standard technique could also be used to routinely monitor and customize chemotherapy.

"It would be possible to check on the progress of a treatment after a day or so to see if anything is really happening," Sotak says. "These treatments are so toxic and make people so sick, and you are frequently working against time, so if something isn't working you want to be able to switch to an alternative treatment as soon as you can. Diffusion-weighted MRI might make that possible."

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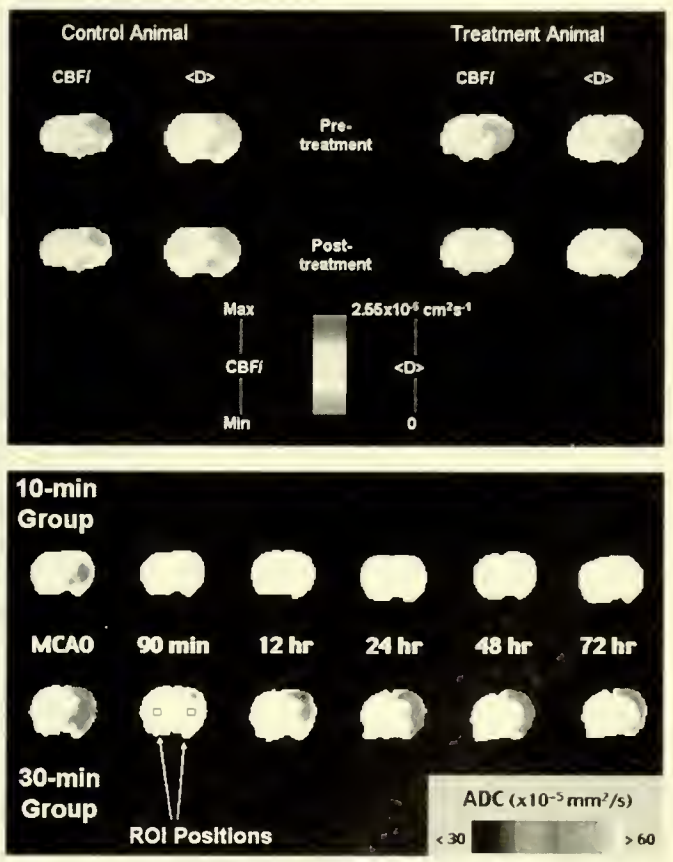

Left, Sotak with graduate student Matthew Silva. Top right (section labeled Treatment Animal): a clot buster drug increases blood flow to the area of the brain compromised by stroke (reduction in the dark area under CBFi) and reduces the apparent cell damage (the dark area under <D>). Bottom right: damage caused by a 30-minute interruption of blood flow appears to vanish, only to reappear within 12 hours and steadily worsen. A 10-minute interruption results in no reappearance of tissue damage.

The unique applications of MRI pioneered in Sotak's laboratory are only part of what has set the facility apart in the field of magnetic resonance imaging. The laboratory's emphasis on education is also unusual—if not unique. "This laboratory is one of the few (if not the only one) in the United States with a research MRI instrument that is fully dedicated to undergraduate, graduate and postdoctoral research and education in biomedical engineering," Sotak says.

Over the past decade, Sotak has worked with two postdoctoral students and advised eight Ph.D. dissertations (five more are in the works), three master's projects and a handful of undergraduate Major Qualifying and Interactive Qualifying projects. He says the fact that the lab has hosted so few master's candidates is a reflection of the daunting complexity of the theory and technology of MRI. "It typically takes a graduate student two years to really get the hang of this stuff. The instrument is very difficult to operate properly. It's also true that career opportunities in the field are open primarily to people with doctorates."

The challenges involved in operating the MRI instrument have also placed limits on the kinds of projects undergraduates can complete in this discipline, Sotak says. In projects undertaken to date, students in various engineering disciplines have computerized physiological instruments used in MRI studies to make them more versatile and easier to use, they have done studies of fluid flow in hollow-fiber bioreactors, and they have even examined the internal anatomy of birds.

With the recent launch of a new undergraduate major in biomedical engineering at WPI, Sotak says he foresees more interest in MRI among undergrads and more opportunities for projects in which the MRI instrument, operated by a graduate student, can be used as a tool for studying various areas of biomedical engineering, especially biomechanics. Some of these projects, he notes, may be in the area of soft-tissue mechanics, the subject of a new research collaboration he has forged with Allen Hoffman, professor of mechanical engineering, and Peter Grigg, professor of physiology at UMass Worcester. Hoffman and Grigg have spent many years studying the biomechanics of tendons using the conventional tools of the mechanical engineer. Sotak plans to see if similar information can be obtained noninvasively using diffusion-weighted MRI.

"Tendons are bundles of long fibers," he says. "Structures comprising those fibers should be impediments to the movement of water molecules. If you place a load on the tendon and cause those fibers to move closer together, the result might be a change in the diffusion coefficient, which we can measure with MRI. Then you would have a noninvasive MRI measurement that you might be able to relate to a mechanical property. We're in the early stages of this work and I'm not sure what's going to happen, but it should be interesting."

For Sotak, who describes himself as a "methods person," someone who enjoys developing and perfecting the techniques of MRI, finding novel ways to apply those methods is the challenge that makes his work fulfilling. "I know all of the history of these methods and have a lot of experience that I can bring to bear on solving problems," he says. "You develop a method for something over here and then you think, 'Yes, that might work over there—maybe there's something about that disease process that would manifest itself in that kind of measurement. If you understand the measurement and its physical underpinnings, you can see how it can be adapted to study other diseases or physical processes. That's why it's helpful to work on a lot of different types of applications. That's also what keeps this job interesting."

Partners for Life

For the past 10 years, WPI and Pfizer have enjoyed a mutually beneficial and rewarding relationship, one that has helped fill an urgent need for chemists in drug discovery and development and provided real-world education to dozens of young men and women.

BY MICHAEL GELBWASSER

Life is our life's work" is the motto of Pfizer, a research-based global pharmaceutical company that develops, manufactures and markets innovative medicines for humans and animals. The company's support for research, projects and programs at WPI is making it possible for many students to expand their educational horizons by engaging in leading-edge research; some even make Pfizer their life's work.

Brian Jones of Coventry, R.I., is one WPI student who has done just that. Jones, who received his B.S. in chemistry in 1997 and his master's in 1998, spent seven months at Pfizer under WPI's Cooperative Education Program. He also worked there during the summers of 1996 and 1997, and did a company-sponsored Major Qualifying Project he titled "LTB-4 Receptor Labeling." Pfizer also supported his graduate research, which expanded on the work he began with that project. Jones is now a process scientist at Pfizer Central Research in Groton, Conn.

"The work I did at and for Pfizer provided me with valuable industry experience that cannot be taught in a college course," Jones says. "My MQP research, as well as such Pfizer scientists as Dr. Lawrence Reiter and Dr. Ralph Robinson, stimulated my interest in pursuing a master's degree. I knew I could continue to work at Pfizer after I received my graduate degree, so it was an easy transition from the university to the workplace."

Since joining the company in 1998, Jones has focused on drug candidates that target diseases related to the central nervous system, with special emphasis on drugs for sleep disorders and alcoholism.

"WPI and Pfizer have enjoyed a rewarding partnership for more than 10 years," says James P. Dittami, head of WPI's Chemistry and Biochemistry Department. Dittami launched the relationship in 1989 when the company agreed to support an undergraduate in his laboratory on a summer research fellowship. "We came together because of our shared interests in medicinal chemistry and drug discovery," he says. "At WPI, we knew that the pharmaceutical industry needed well-trained, motivated employees and we believed Pfizer would benefit from getting to know some of the extraordinary students we educate.

"We saw a lot of students going into such fields as biology, then recognizing too late that they couldn't get the jobs they wanted at drug discovery companies because they lacked appropriate training in chemistry. Our connection to Pfizer makes it possible for us to prepare our students for the exciting and challenging field of medicinal chemistry."

Pfizer administrators were receptive to the collaboration from the beginning, according to Dittami. "WPI continues to work with Peter McCarthy, senior executive director and head of chemistry recruitment, who is active in promoting new partnerships between scientists at Pfizer and WPI. The company hopes that by supporting WPI programs and students it will help increase the pool of

highly qualified, dedicated scientists entering the field of organic chemistry. Chemists who have training in small-molecule synthesis are in great demand. In fact, WPI has established relationships with several other companies, including Pharmacia & Upjohn, BASF and Astra Pharmaceuticals. As a result, we can guarantee 100 percent placement for WPI graduates with solid backgrounds in this area of chemistry."

Forty-seven WPI alumni are currently employed as scientists, engineers and managers at Pfizer, the majority at the Groton facility. Over the years, the company's support for WPI has expanded to involve a variety of collaborative programs on campus and in Groton. John LaMattina, Pfizer's vice president for world discovery operations, chairs WPI's Chemistry and Biochemistry Advisory Board.

"Our relationship with WPI is a mutually beneficial one," says LaMattina. "It has many aspects. Pfizer scientists often come to WPI as guest lecturers, to give presentations to students, or to present topics in Professor Dittami's graduate-level course in medicinal chemistry. Our company has also donated valuable equipment to the University. We've provided cash donations to support the University's Nuclear Magnetic Resonance facility, and have made grants for education. These contributions are designed to increase the experience and depth of knowledge of WPI students. From our perspective, this provides excellent preparation for joining a major pharmaceutical company like Pfizer."

Here is a description of the programs Pfizer currently sponsors at WPI:

Summer Research Fellowships

Pfizer Summer Undergraduate Research Fellowships (SURF) are prestigious, highly competitive awards offered to specific departments at selected colleges and universities nationwide. Robert A. Volkmann, senior research fellow and head of SURF, directs the program and assembles the Pfizer committee that selects the winners. The fellowships include a $3,500 student stipend and up to $1,500 for departmental expenses to support the student's research, which concludes with a poster presentation at Pfizer Central Research.

The program began at WPI when Steven J. Rigatti '91 was named the first Pfizer Summer Research Fellow. The program has since been expanded beyond the University. This year, Pfizer invested $400,000 to support 80 students at 64 colleges and universities; three of them are at WPI.

Rigatti spent the summer of 1989 working with Dittami on a special class of reactions known as photo-rearrangements. The reactions use light to reorganize the atoms in a molecule. The research was aimed at developing ways to apply these reactions to the synthesis of biologically active and medicinally relevant compounds. The work was, in part, the basis for an article in *Tetrahedron Letters*, an international journal for the rapid communication of results in organic chemistry.

A chemistry major, Rigatti went on to earn an M.D. at the University of Connecticut and is now a physician with Old Saybrook Family Practice on the Connecticut coast. "My Pfizer summer research fellowship was my first exposure to 'real science,'" Rigatti says. "Although I did not choose to pursue a career in chemistry, I feel that the publication of my project report was an important factor in my acceptance to medical school."

PHOTOS BY PATRICK O'CONNOR

Top, Pfizer summer research fellow Kyria Prevost, left, is working in the lab of Kristin Wobbe, professor of chemistry and biochemistry. Bottom, at Pfizer Central Research in Groton, Conn., are, from left, Brooke Clark '00, Douglas Wilson '96 and Brian Jones '97.

Douglas Wilson, who graduated from WPI in 1996 with high distinction in chemistry, was a Pfizer fellow in 1995. Wilson's MQP, "Studies Directed Toward the Mechanism of Photoinitiated Ylide-Alkene Cycloaddition Reaction," won a 1996 Provost's MQP Award. Dittami was his advisor. Wilson now works as an assistant scientist at Pfizer Central Research.

To date, about 20 WPI students have received these fellowships. The 1999 fellows are Jessica Condon, a junior who is carrying a double major in biotechnology and biochemistry, Karen Hoffman, a junior majoring in chemistry, and Kyria Prevost, a senior majoring in biochemistry.

PREPARE fellowships

Last year, Pfizer committed $100,000 to establish PREPARE (Pfizer Research and Education Program and Recruiting Enterprise) as a pilot program with four schools and about 20 students overall. Open to juniors majoring in chemistry, the program was created by Pfizer scientists Hiroko Masamune and Michael DeNinno as a means of increasing the number of experienced organic chemists to fill positions in drug discovery and development. Each student receives a stipend for summer research, which involves multistep synthesis and provides exposure to diverse synthetic methods. The students continue their research through the academic year by completing major projects.

At WPI, PREPARE fellows work with Dittami and James W. Pavlik, professor of chemistry and biochemistry. Fellows receive training in small-scale synthesis, anhydrous techniques, nuclear magnetic resonance spectroscopy, mass spectroscopy and other methods of characterization. They also gain experience in conducting interactive searches using electronic databases and library resources. During the program they give an oral presentation on the progress of their projects to their Pfizer liaison, who provides feedback on the work. The research culmi-

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Clockwise from left, James Pavlik, professor of chemistry and biochemistry, Pfizer PREPARE fellows Richard Benetti '00, Bryan Hayes '00 and Erik Kataisto '00, James Dittami, head of the Chemistry and Biochemistry Department, and Pfizer summer research fellow Karen Hoffman '01.

nates in a poster presentation delivered at Pfizer Central Research.

In 1998, WPI received $30,000 in PREPARE fellowships, which were awarded to five students. This year, Pfizer increased its commitment to $165,000 and expanded the program to include seven schools and about 30 students. WPI received $20,000, which is supporting the work of seniors Richard Benetti, Bryan Hayes, Erik Kataisto and Alisha Spafford.

Support for MQPs and Graduate Research

Pfizer sponsors Major Qualifying Projects that provide opportunities for WPI seniors to do proprietary research under the direction of a member of the WPI faculty and a Pfizer scientist. While the MQPs are carried out at WPI, students also often visit the Groton facility to do on-site experiments and consult with advisors. Emma Rose Palmacci, a 1997 Pfizer Undergraduate Research Fellow, also completed a company-sponsored MQP. Dittami and Lawrence Reiter, principal research investigator at Pfizer, were her advisors. The project, "MMP-13 Inhibitors Containing a Sulfone as the Zinc Ligand," was one of the winners of the Provost's MQP Award in 1998. Palmacci graduated with high distinction in chemistry with a medicinal chemistry concentration and is currently pursuing a doctorate in chemistry at MIT.

Over the years the company has also provided support for the research of several WPI graduate students. It funded Jones' work in 1997-98 with $40,000, and since August 1996 it has provided $140,390 to support the research of Yi Liu, a Ph.D. candidate in chemistry. Liu is working to uncover new methods for the synthesis of prostaglandins. "Prostaglandins are naturally occurring substances found in humans and animals that play an important regulatory role in many normal cellular functions," explains Dittami.

Our longtime, thriving relationship with Pfizer has had a substantial impact on our educational and research programs," says Provost John F. Carney III. "The research opportunities, the expertise Pfizer scientists so generously share with our students and faculty, and the time Pfizer administrators spend with us as advisory board members, mentors and consultants has contributed greatly to the breadth and quality of the education we offer to students interested in the innovative and exciting world of pharmaceuticals and drug discovery."

"There will be significant advances in drug discovery in the next millennium that will require a cadre of well-trained scientists," adds Dittami. "Our partnership with Pfizer has given us a good start on training the next generation of scientists. I hope this relationship will continue for many years to come. Based on our prior success, we fully expect that it will."

—Michael Gelbwasser is editor of the Foxboro Reporter, *a daily newspaper in Foxboro, Mass.*

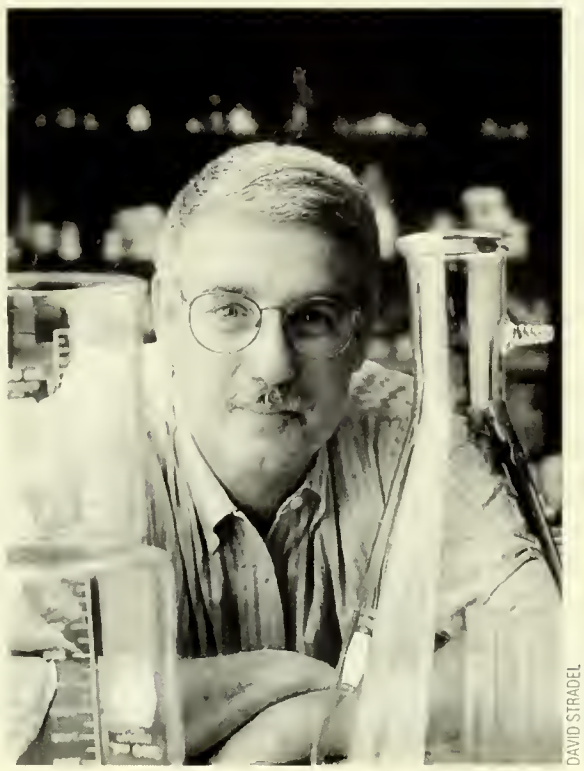
Spawning New Therapies

As vice president of a biochemical manufacturer, Joseph Toce helps supply other companies with the raw ingredients for drugs that combat AIDS, cancer and a host of other diseases. To get those ingredients, Toce turns to an unexpected source.

BY BONNIE GELBWASSER

The building blocks of this industrial chemist's career aren't made of brick or concrete. Instead, they are the building blocks of DNA, the double-stranded molecule that contains the code of life.

Joseph Toce is a vice president of Reliable Biopharmaceutical Corp., a St. Louis-based bulk manufacturer of nucleic acids, biochemicals and enzymes for the pharmaceutical and biotechnology industries. The company is one of the world's largest producers of deoxynucleosides and deoxynucleotides, some of the components of DNA. It isolates them from salmon milt, the fish's sperm duct, which has proven a rich source of DNA.



DAVID STRADEL

A native of Hartford, Conn., Toce graduated from WPI in 1970 with a bachelor's degree in chemistry. He earned a doctorate in biochemistry at the University of Wisconsin, Madison, in 1979 and began his career at Sigma Chemical in St. Louis. He joined Reliable as director of research and development in 1984 and became a partner in 1989.

In March 1998, he was one of 68 honorees to receive the Tibbetts Award from the Small Business Innovative Research (SBIR) Program. The award is named for Roland Tibbetts, a longtime advocate of small business participation in government research who retired from the National Science Foundation in 1996. Toce was honored for "a cascade of developments his work has produced and for furthering biotechnology and fostering high-tech business growth." Under Toce's leadership, Reliable won a total of seven SBIR Phase I and Phase II grants from the National Institutes of Health in 1989 and 1990.

The process of isolating DNA from salmon milt begins with salmon fisheries, primarily in the Pacific Northwest. Fishermen harvest the sperm ducts from sexually mature salmon, usually chum salmon (the most common variety), when the fish return to the area's waters to spawn. "The fisheries remove the whitish-pink milt, which resembles a large, flat hot dog or a piece of bologna, when they gut the salmon for meat or other uses," says Toce. "It is then flash-frozen and shipped to us.

"With assistance from the SBIR grants, we developed what I refer to as 'slop-bucket biochemistry,'" he explains. "The technique enables us to break the DNA down and then isolate the four basic building blocks from it. The milt is ground up, precipitated, digested and purified to produce the building blocks, which end up as a bunch of white powders that we sell as a commodity. It's like buying a chemical off the shelf. We process about 100,000 pounds of milt to get 1,000 kilos of nucleosides. Our capacity exceeds two million pounds of milt per year. The company is the only one in North America doing this type of work. All of our competition is in Japan."

Toce's work has led to major developments in the production of drugs for AIDS, cancer and other viral diseases, increased the size of Reliable's work force from 15 to 55, and generated millions of dollars in sales. In addition to Toce, the company currently employs three other Ph.D.s, plus 45 bachelor's- and master's-level chemists, and support staff.

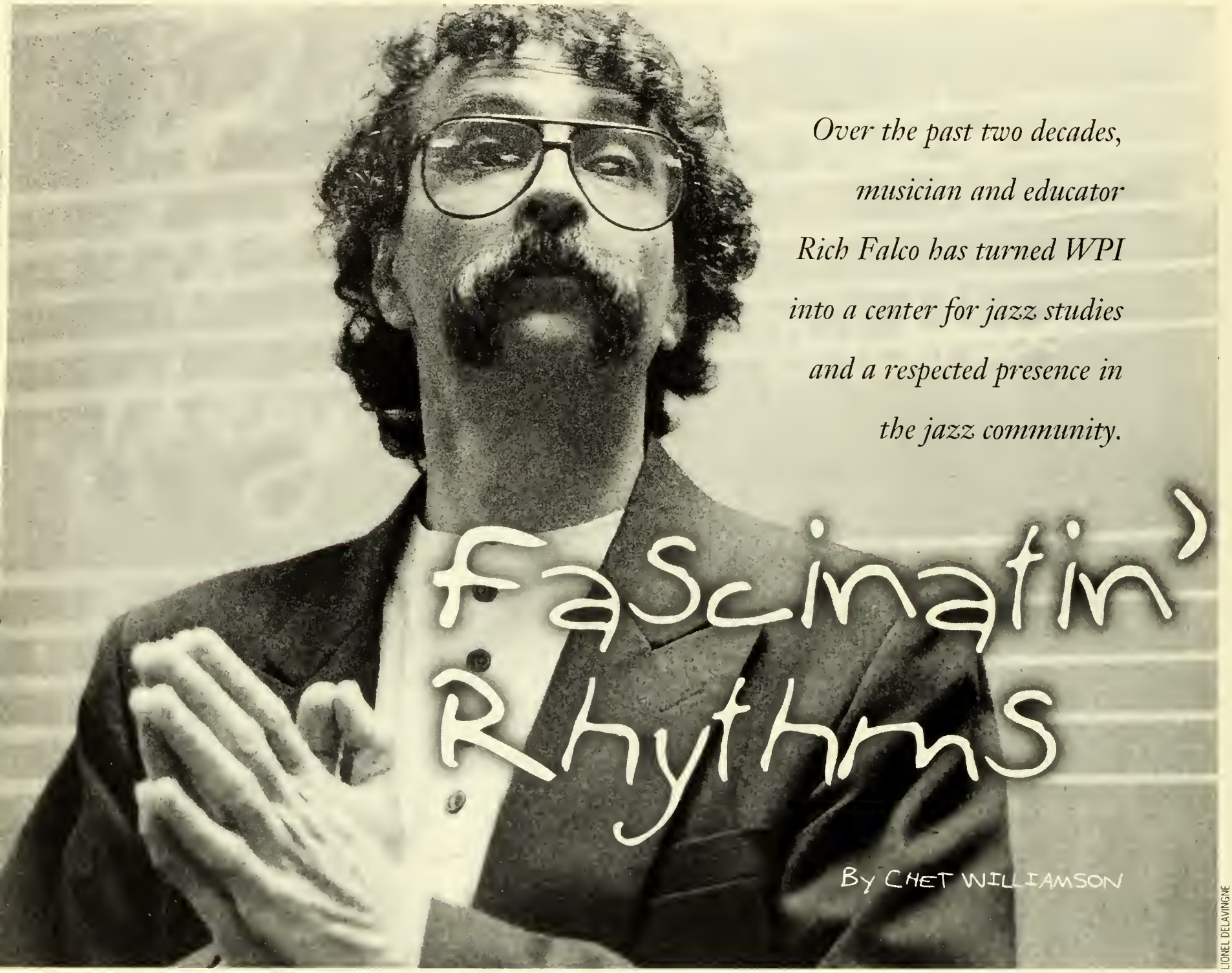
In 1993 Reliable opened a new, technically sophisticated 51,000-square-foot manufacturing and biotechnology center on 4.8 acres. In addition to isolating DNA, it also offers producers ultrapure biochemicals, bulk pharmaceuticals and enzymes.

William Ash, Reliable's president and owner, founded the company as Reliable Chemical in 1968. It currently serves more than a dozen publicly traded NASDAQ companies, such as Isis Pharmaceuticals and Hybridon, which require large quantities of DNA building blocks to bring drugs to market.

The technique Toce developed allowed the company to commercialize the DNA building block production process and make it available to its customers at a much cheaper cost. "Biotechnology companies need significant quantities of materials," he says. "It takes a minimum of seven years and several hundred million dollars from the time a scientist comes up with an idea for a therapeutic drug until it's out. That's been a problem. Most of the drugs we and our customers are involved with are in clinical testing or preclinical testing situations. The things we deal with are years away from the market.

"This is a production facility," he adds. "We are in the business of making products, not discovering new drugs. We're a wholesale manufacturer. For example, in the AIDS drug AZT, we isolate the T. Other companies put the AZ on. We do not make the finished pharmaceutical tablets, but we do produce the active pharmaceutical ingredients (API) in bulk and under FDA inspection. These go to companies that make final finished pharmaceuticals and they do the formulations to the final dosage. It's really two separate processes.

"We are driven by what our customers tell us they need. Every day brings something new, though some projects are pretty mundane and straight up. We have expanded into a whole new area of nucleic acid-based chemistry. We're producing deoxynucleoside triphosphates used in polymerase chain reaction (PCR) for DNA fingerprinting and sequencing the human genome. Nuclei acid chemistry research has brought us new customers involved with genetic material—whether it's anticancer or viral drugs."



Over the past two decades, musician and educator Rich Falco has turned WPI into a center for jazz studies and a respected presence in the jazz community.

fascinatin' Rhythms

By CHET WILLIAMSON

LIONEL DELAVIGNE

The rehearsal begins with the tuning note.

Blown through the bell of a trumpet, a single, yawning B-flat fills the air like a foghorn in search of light. Picking up this fundamental frequency, the ensemble responds to the call. At first the bleating sound is nothing more than a field of white noise.

"Okay, the idea is to try to match the pitch to everyone else in the ensemble—for those of you who've lost that concept," deadpans director Rich Falco. His humor sets the 23 members of the WPI Stage Band at ease. "Let's try it one more time. Concert B-flat, everyone."

Once again the room swells with the note. As the aural formation falls in line, cacophony is transformed into a meadow of harmony. Having just returned from a long holiday break, the students seem to need a little help getting back into the groove. Falco flips through his charts looking for a number that will get their juices flowing.

"Right now, more than anything, we need to play. We haven't played in a few weeks. Some of you, literally, haven't played in weeks," he says wryly, looking around the room. "I'd like to start

with something exciting; something that pushes the edge a little bit. Let's take out 'Hit and Run.'"

"Hit and Run" is a modern jazz chart written for trumpeter Maynard Ferguson. The tune breaks out fast and bristles right through to the finish line. "Okay," Falco shouts again, snapping his fingers to set the tempo. "Let's review some of the concepts. This is bebop. Straight-ahead. All unison writing, for the most part. There are going to be some misplaced figures, a la Thelonious Monk." He scats a few tritone figures: "Be do, be do, bebop."

Tom Hall '00, a trombonist in the band, says Falco conducts with an encouraging spirit that students find inspiring. "He really is jazz," says Hall, a junior completing a double major in electrical engineering and music. "He's excited about it. He's not a dictator on the podium. He knows what he wants, though, and conveys that to us. His enthusiasm really feeds our fire."

Falco directs the band like a traffic cop who's taken lessons from a matador. He is graceful and mechanical—springing toward the sax section to bring down the dynamics, standing on his toes when the trumpets need to reach, clapping his hands emphatically when the tempo falters. Visualizing the beat, he flags his hands left to right, up and down. He is a rare bird in the music community—a jazz conductor.

Still finger-popping, he adds, "The front part is straight-up unison. When you are doing unison playing, you want to get a little bit of an edge to your sound...without a lot of volume. Tuck into the rest of the section. Everybody equal in volume. Okay, one, two ... a one, two, three, four...."

LIONEL DELAVIGNE

PATRICK O'CONNOR

The WPI Stage Band is one of three award-winning jazz performance groups at the University. Under Falco's direction, the groups play 20 to 30 times throughout the academic year at concerts and festivals, on live radio and television, in recording sessions, and in joint programs with other colleges across the country. Each group also takes part in community outreach programs, bringing music to such local organizations as the Muscular Dystrophy Association, the UMass Medical Center Children's Association, and the United Way.

This year, Falco marks his 20th anniversary as a teacher of the art and science of jazz at WPI. As director of jazz studies, he not only conducts all three WPI jazz ensembles, but lectures on the history and theory of this uniquely American art form. His tenure began when he was asked to sign on as a visiting instructor to organize and conduct the school's first two jazz ensembles.

"It was a natural progression," Falco says. "Initially, there were performance ensembles that began to grow. It soon became obvious that students needed to know jazz and popular music theory and jazz history, so that they could understand stylistic performance practices—to approach the music from an area other than just reading what was written on the page.

"So that necessitated classes in those two areas. The program expanded as student interest in the ensembles fed into the academics. In some sense, it's almost like the tail wagging the dog: academics being driven by student interest in the ensembles. Although, it's not only jazz performance students who take these classes. There is wide campus interest."

Describing the 40-something Falco is like trying to sketch a bird in flight. One part jazz hipster, one part college professor whose engaging personality and youthful energy are disarming and infectious, he is wiry, intense, constantly on the move. With a face framed by curly black hair, he wears wide-eyed glasses and a Fu Manchu mustache.

Falco was born and raised in Worcester, where he lives with his wife, Lucia Clemente-Falco, and their daughter, Mattina. He played guitar as a child and started lessons at 15. He attended Berklee College of Music in Boston, where he studied guitar with Bill Leavitt and special big band and ensemble techniques with Herb Pomeroy. Long before his arrival at WPI, he was well known as a jazz musician in Central New England. He remains active as the leader of the Rich Falco Jazz Quartet, which plays mainstream, contemporary and Latin jazz in concert venues throughout the area and is currently recording a new CD.

"It was a natural progression....The program expanded as student interest in the ensembles fed into the academics. In some sense, it's almost like the tail wagging the dog."

Over the years, Falco has become a prominent figure in the Central Massachusetts jazz community. He is past president of the Jazz Worcester Society and

founder and artistic director of the Jazz Worcester music festival. He has taught at Clark University, where he also directed the Jazz Workshop and Jazz Combo. He offers private instruction in jazz guitar and improvisation at the Clemente Guitar Studios in Worcester. Walter Crockett, longtime chronicler of music in the area, once wrote, "Falco is one of those few people whose removal from the Worcester scene would cause an audible decline in the quality of life."

"It takes a great amount of training to play this music. It is a very sophisticated language. I tell students that, unlike vernacular, this is more like a poetic language."

That's a sentiment shared by many WPI students and alumni. Says Mike Andrews '97, a graduate student working on a master's degree in electrical engineering who started playing jazz in the ensembles as a freshman, "Rich Falco is basically my guru.

"I was a fairly strong high school musician, and I wanted to continue playing on some level. Having the jazz groups here was just amazing. It blew me away. The emphasis was more on the process and less on the product. I remember one rehearsal where we worked on 'Blue and Green' by Miles Davis. It's difficult to improvise on. It's a 10-bar form and the changes loop back on themselves. We spent the entire rehearsal trying to build the connection."

JOHN GILLOOLY

PATRICK O'CONNOR

Under Falco's direction, jazz studies at WPI has blossomed into an internationally recognized program. Various ensembles have performed extensively throughout the United States and in Western Europe (France, Belgium and Luxembourg), Eastern Europe (Russia and Romania), Central Europe (Austria and the Czech Republic) and Egypt. Last year WPI's jazz musicians traveled to Spain, and plans are in the works for more travel in the year 2000, to either Greece or Italy.

"We've done five tours abroad," Falco enthuses. "It's very interesting to see the reaction of folks when an American group is playing American-made music. It's interesting to get their perspective—the music is so representative of the American spirit.

"It takes a great amount of training to play this music," Falco explains. "It is a very sophisticated language. I tell students that, unlike vernacular, this is more like a poetic language. It is necessary to actually study nuance, understand syntax, and understand a lot of what is being subtly stated or understated. This becomes an area of exploration as opposed to something like a rock vernacular where everything is right out in front."

Engineers and jazz musicians often find themselves speaking a common language. The vertical and horizontal groupings of music—harmony and melody—can often suggest patterns similar to those found in mathematics and science.

"There are a lot of patterns that crop up in jazz," Andrews says. "Specifically, numerical patterns that can transfer to a pattern of notes. A lot of my practice is thinking of numerical patterns—working them out in my practice sessions. Then they will come out as organic material when I'm playing. It's really interesting to see how engineers react to jazz. We're quick to absorb all the technicalities of the music. Rich Falco has figured out exactly what students in a technical environment need to absorb this music."

Jazz is a relatively new field of study on American campuses. It didn't become widespread until the 1960s. Before that it was largely an underground music learned in private studies and on the bandstand. "Historically, there have been two lines of thinking on jazz education," Falco says. "One is that the music can only be taught one-on-one. You need a mentor relationship. This is the way it was taught through the late 1940s and into the 1950s."

Since then, Falco says, jazz has become more academic, much like the traditional European approach to music education. "At WPI, I have an opportunity to do both," he says. "I can do something in the classroom for folks who are not players. On the other hand, I've got a college big band and a smaller jazz ensemble. They perform often, much more than groups typically do even at conservatories and other music schools."

When they are not playing, jazz performers at WPI are exposed to some of the greatest jazz artists working today. Through the jazz studies program, WPI has presented in concert such performers as

PATRICK O'CONNOR

The versatile jazz ensembles directed and conducted by Rich Falco perform more than 20 times each year in venues formal and informal.

Dizzy Gillespie, Clark Terry, Sun Ra, Curtis Fuller, Ralph Towner, Jaki Byard, Max Roach and Pat Metheny. Has having these jazz masters on campus enlightened students? "Absolutely! No question," says pianist/electrical engineer Jim Heffernan '85. "The WCUW Concert Series in the early 1980s had national figures like Anthony Braxton, Vinnie Golia and Archie Shepp. Most of the concerts were held downstairs in Alden Memorial, in this nice little warm setting. That was happening!

"At the same time, we were playing in Rich's groups. There was a real sense that we were on to something really good here. Even though we were just beginning and had a lot to learn, there was a sense of depth. It's the sort of thing that gives you the fuel to keep going and exploring the art form—when you see these incredible masters and they are sitting right in your school. Then, the following Wednesday night, you're playing in the same room, on the same piano they played on. Those were very valuable experiences."

Falco says WPI brings at least one international artist to campus every year to do a clinic, workshop or performance. "In recent years, we've tried to focus on the younger players. This year we had Christian McBride. We had Cyrus Chestnut last year and Mark Whitfield the year before." Last November, McBride, who has worked with Wynton Marsalis, Chick Corea and the late Betty Carter, among others, conducted a workshop and clinic featuring the WPI Jazz Ensemble and the International Association of Jazz Educators Massachusetts All-State Combo.

"Jazz in Our Midst" is another outstanding feature of the jazz studies program. "This gives our students a lot of exposure to regional players," Falco says. "And it makes regional players aware of the college." Last December, local trumpeter Jerry Sabatini conducted a clinic titled "Jazz Improvisation and Composition." In March, flutist Abby Rabinovitz offered another, called "Indian Music in Jazz: Exploring the Boundaries." More recently, guitarist and composer Troy Nielsen '91 presented "Jazz and the Avant-garde." Nielsen has designed a workshop for exploring modal and free jazz performance techniques from a historical perspective.

"When you see these incredible masters and they are sitting right in your school. Then, the following Wednesday night, you're playing in the same room, on the same piano they played on."

Through his professional activities, Falco works to place WPI's musical talents on display for the next generation of jazz musicians. He is a judge and clinician for the International Association of Jazz Educators (IAJE) and the Massachusetts Music Educators for Central District and All State. He serves on the festival committee and is the host for the IAJE All State Jazz Combo and Jazz Choir Festival at WPI. Every year more than 200 of the best high school jazz students compete in front of nationally recognized judges.

Given the many ways Falco has cultivated jazz—on and off campus—one could argue he is an improviser of the highest order. Falco shrugs off the praise. "We're trying to establish WPI as sort of a jazz center—and coming at it from a lot of different angles. It is wonderful to see the week-to-week growth of the students—their ability to manage themselves as mature musicians and to express themselves in a complex language. That is the joy of teaching, especially at a university like WPI."

—Williamson, a freelance writer and musician, is also arts editor for Worcester Magazine.

WPI's first off-campus project center was launched in the nation's capital 25 years ago. After all these years, it remains one of the hottest spots for student project work.

A Silver Anniversary in D.C.

PHOTOS BY BRUCE CRAMER

In 1974, two years after the implementation of the WPI Plan, the University established its first off-campus residential center for student project work in Washington, D.C. It was the first step in a steady march that has taken WPI around the globe. Today, through the Global Perspective Program, about half of the University's juniors and seniors head out to one of 10 project sites on five continents to tackle important problems and issues for agencies, organizations and corporations, making WPI the acknowledged leader in global technological education.

Washington was selected as the site of the first residential project center because of the wealth of opportunities that exist in the nation's capital to examine societal and political issues within a technical context for the broad range of government, professional and special-interest organizations headquartered in the city. The procedures and policies worked out in Washington for off-campus project advising provided a solid foundation for other centers established over the last quarter century.

Every year since the center was founded, teams of students have traveled to Washington in the late fall to complete Interactive Qualifying Projects with federal, private and nonprofit agencies and organizations. In all, about 300 projects have been completed in the city. Last fall, 28 students in eight teams spent seven weeks at the center working with faculty advisors Chrysanthe Demetry, Norton Associate Professor of Mechanical Engineering, and Angel Rivera, assistant professor of Spanish. (Susan Vernon-Gerstenfeld, adjunct associate professor of interdisciplinary studies, directs the center.) Here's a brief look at what those student teams accomplished:

The Greening of Our Cities

Urban planners and policymakers often overlook the benefits that urban forests provide to their surrounding communities. Juniors Ryan Avey, Milissa Cormier, Manna Neghassi and Carl Nielson took a look at whether an economic analysis of tree cover might help address the major environmental concerns of the Chesapeake Bay area and influence public policy and urban planning nationwide. The goal of the project, commissioned by the nonprofit organization American Forests, was to gauge the benefits of tree cover to storm water management, air quality and energy conservation. The students also determined the effectiveness of a computer program called CITYgreen by using the software to analyze the tree cover in Arlington, Va., and Baltimore, Md. They gave high marks to the program, which they described as "a good tool for educating communities on tree-cover benefits that could potentially impact urban planning and policy making in those areas."

Beware of Hedge Trimmers

The Consumer Product Safety Commission (CPSC) estimates that more than 225,000 people were treated in hospital emergency rooms in 1996 for injuries caused by lawn and garden tools. Jeremy Dexter '00, Mark Oliveira '99 and Brian Rapp '00 collected data about injuries related to gasoline-powered lawn and garden equipment and interviewed representatives of trade organizations, rental outlets and retail stores to determine how best to reduce the hazards associated with their use. The students discovered that homeowners were most often injured by hedge and lawn trimmers (edgers and log splitters were the second and third most dangerous devices). The most common type of injury was caused by an object hitting the eye of the operator. As part of their IQP, the students produced a reference booklet for lawn and garden power equipment that will help the CPSC look at the safety of these tools in the future.

Engineering for Ecology

Cleaning up the environment starts with public education. That was the conclusion reached by juniors Richard Bradshaw, Uri Braun and Simon Nance, who completed a case study of contaminated sediment creation and removal in the Baltimore area of the Chesapeake Bay for the National Science Foundation. The project's goal was to address the direction and sustainability of ecological engineering, which the students described as "a perspective or systems approach to environmental management that ties the environment and local society together in a conscious symbiotic relationship, sharing costs and benefits." They concluded that while it is not easy to reach mutually agreeable solutions to problems such as this, the best way to begin is to improve education and communication. "The NSF can give support to those elements," they wrote, "by aiding projects that promote public ecological education, industrial cooperation and local public awareness, responsibility and involvement."

Safe Sailors

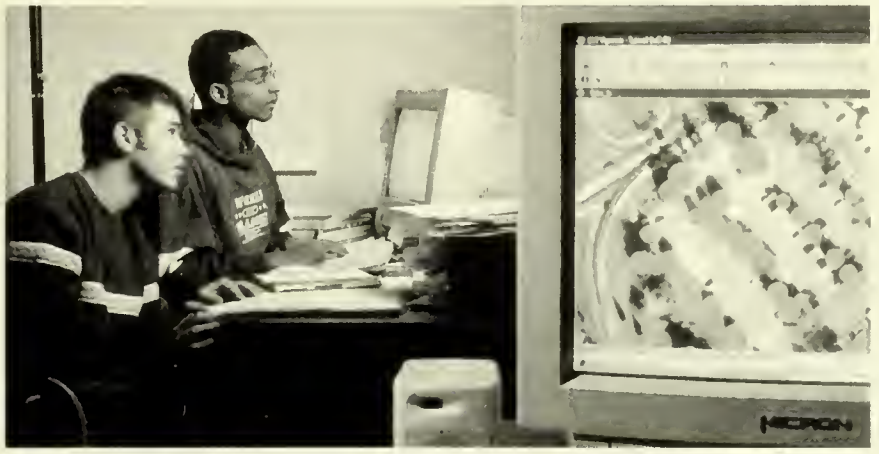
The U.S. Coast Guard commissioned a project to evaluate and improve the medical and physical standards applied to merchant mariners to determine if they are meeting the needs of the maritime community while ensuring a safe environment at sea. For their IQP, Jeremy Bernier, Matthew Ericson, Joseph Malboeuf and Crissy Montgomery, all members of the Class of 2000, gathered information from mariners, marine labor unions, medical professionals, examiners in regional centers, National Maritime Center administrators, advocacy groups and agencies of the Department of Transportation. They gave their stamp of approval to the physical and medical standards currently used to ensure that mariners are fit for duty. "The process used to apply the standards appears to be allowing all capable mariners to work in the industry," they wrote. Their recommendations included standardizing the process of determining fitness for duty and improving documentation of marine accidents and injuries.

Improving Access to Web Education

Science, math and engineering professors may have easier access to high-quality education through the World Wide Web, thanks to an IQP completed by Benjamin Clark '00, Adriano Palombizio '99 and Taryn Syverain '00. The National Science Foundation's Division of Undergraduate Education sponsored the project, in which the students analyzed professors' opinions and assembled focus groups to determine how to break down the barriers to Web-enhanced education. The students used the Web to conduct their research at George Washington University, Georgetown University, the New Jersey Institute of Technology, Prince George's Community College, and Florida Agricultural and Mechanical University. Their recommendations were based on what they called "the five Ts": technology (hardware), technical support, time, tools, and tenure and other incentives. Each T provides a key to resolving the problems teachers find in trying to implement Web-based studies.

Perfecting Product Patents

A commercial database, used wisely, can improve the way the government examines patents for new products, according to juniors Adam Blomberg, Thomas Hall and Jason Katz, whose IQP was sponsored by the U.S. Patent and Trademark Office. In 1997 the PTO spent about $9 million on commercial databases it used in prior-art searching; the total escalated to $12 million in 1998. Directors of the PTO's Technology Center 2700 wanted to justify their portion of this expenditure. Because no data on the use of these databases by the Technology Center was available, the team focused on measuring effective use, providing helpful data, and identifying methods for improving the effectiveness of commercial database searches for patent examiners. They reached a number of conclusions about how the center could improve tracking methods and which commercial databases were most useful and successful. They also made time- and energy-saving suggestions intended to simplify future database tracking. Their recommendations include enforcing office policy on required paperwork for patent applications, modifying forms, and using a database to track applications.



Opposite, Carl Nielson on the Washington Mall. Top, Ryan Avey, left, and Manna Neghassi completed a project on urban forestation for American Forests. Bottom, Joseph Malboeuf, left, and Crissy Montgomery, right, with a liaison from the U.S. Coast Guard, which sponsored their project on the medical and physical standards applied to merchant mariners.

Sea Grant on the Web

Colleges and universities with marine science programs may soon enjoy online information resources, thanks to a project completed by Ryan Barbini, Jonathan Manning, Darren Ranalli and Christopher Stank. The IQP team, all juniors, created a prototype Web site for the National Sea Grant Office's policy reference material. The information, currently contained in several loose-leaf binders, included a policy manual that had become badly outdated. To improve Sea Grant's organizational communication, the students conducted interviews and surveys that provided the updated information they needed, then created a prototype for the Web site that will allow the agency to update the data quickly and inexpensively. The National Sea Grant College Program, a department of the National Oceanic and Atmospheric Administration, sponsored the project. Sea Grant funds projects in the marine sciences and operates through 29 coastal colleges and universities that report to the national office. Ronald C. Baird, former director of corporate relations at WPI, directs the National Sea Grant College Program, which is based in Silver Spring, Md.

Marketing the NSPE

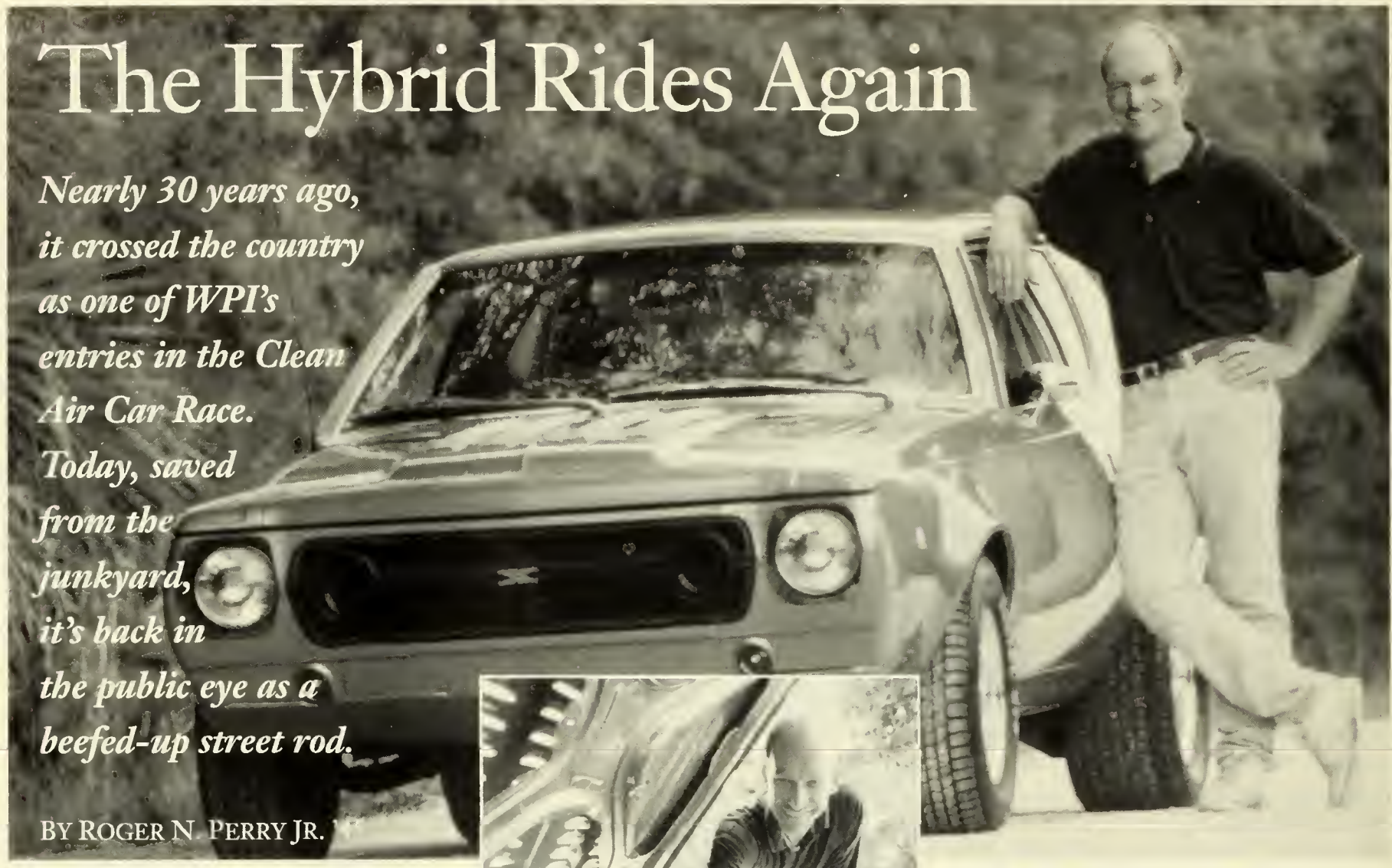
Matthew Denicourt '99, Ryan Fournier '00, Sowmya Luckoor '00 and Angela Malaquias '00 developed an action plan that focused on communication and marketing strategies the National Society of Professional Engineers might use to increase student membership. The team used interviews, surveys, focus groups and benchmarking analysis to gather opinions and develop recommendations. They found that personal communication would help keep student members involved and that students put a high value on help they receive in preparing for exams and employment interviews and in learning about their major. They recommended reviving NSPE's Student Services Department and establishing a liaison in each of the society's six membership regions, developing products and services to present to new student members when they apply, and reorganizing the Web site to advertise student benefits and make the existing career development system better known to students. NSPE plans to use the action plan on all of its organizational levels.

—ARLIE CORDAY

The Hybrid Rides Again

Nearly 30 years ago, it crossed the country as one of WPI's entries in the Clean Air Car Race. Today, saved from the junkyard, it's back in the public eye as a beefed-up street rod.

BY ROGER N. PERRY JR. '



PHOTOS BY J.B. MCCCURTNEY

Ron Enamait with his transformed 1970 AMC Gremlin and its specially designed 650-horsepower engine.

The 1970 AMC Gremlin that once required two minutes to go from 0 to 60, now gets there in just four seconds and can cover a quarter mile in 11 seconds. The car, one of five modified by WPI students for the 1970 Clean Air Car Race, was then a hybrid vehicle outfitted with electric and gasoline engines. Today, after languishing for nearly three decades, it's back in the public eye, this time as a souped-up speed demon owned by Ron Enamait of Wimauma, Fla.

The Clean Air Car Race was a national event organized by students from MIT and Caltech to create public awareness of the growing problem of air pollution from automobile emissions. A total of 42 student teams from 36 colleges and universities accepted the challenge to develop a vehicle that would achieve a reduction in emissions during the weeklong trek from Cambridge to Pasadena. The team that modified the Gremlin was one of two from WPI to place first in their respective divisions.

In urban areas the hybrid car was driven by an electric motor powered by 26 lead-acid storage batteries. In open country, an internal combustion engine drove the DC motor, which then became a generator to recharge the batteries and power the drive train. The weight of the car, without drivers, was 5,600 pounds.

The team of WPI designers, builders and drivers included Steven Clarke '70, William Medeiros '70, David Nowack '71, Norman Sousa '70 and Kenneth Maymon '70. Their faculty advisor was Roger Borden, professor of mechanical engineering. Although plagued with overheating problems, particularly in the desert Southwest (at one point a plastic flashlight melted on the metal floor), the team amassed enough points to easily win the hybrid division trophy.

(For a comprehensive account of the Clean Air Car Race, see the Fall 1970 *WPI Journal*.)

"At the time of the Clean Air Car Race, I had just been discharged from active duty with the U.S. Army and didn't know anything about it," says Enamait, a graduate of the University of New Haven. "When I lived in Connecticut, I worked for about five years in the office of Moroso Performance in Guilford. One of the people I met there was the company's chief engine builder, Bob Rinaldi, who now builds engines for the prestigious Roush Racing in Charlotte, N.C.

"I told Bob about my plans to build a 'street rod' and he agreed to do the motor for me. A month or so after I left an engine block in his shop, he called to tell me he had the motor all done. So I had this race-built AMC motor and nothing to put it in.

"I wanted something light for the best performance," says Enamait, "a car that wasn't going to give me suspension problems. All things considered, the Gremlin was at the top of my list. As I was looking through the local *Bargain News*, I spotted an ad that said, '1970 Gremlin, 3,600 original miles, best offer.' I called immediately and rushed over to look at it. When I first went

into the garage, I went from being ecstatic to quite disappointed. This wasn't the cream puff just driven on Sundays by a little old lady I'd expected to find.

"The inside was pretty well gutted," he recalls. "The roof was caved in and there were air vents still attached to the rear quarter panels. Still, the sheet metal on the body was in great condition, like it just came out of the showroom. The owner told me he had planned to restore the car himself but never found the time. So after a few minutes of the requisite haggling, I bought it."

"When I purchased the Gremlin from the school back in the late 1970s, my intention was to regenerate it," says Paul J. Landino '76, who sold the Gremlin to Enamait. "My interest in the car began with the senior project I did at WPI on redesigning the motor controller of the Hybrid Car. This project actually inspired my interest in motor controls, which eventually led to my starting a business in AC motor controls. When I learned that WPI would consider an offer for what was left of the Gremlin, I took it home like an old friend."

Back home in Connecticut, Landino began outfitting the car with an AC motor drive system. The work slowed because of tight finances as he started his business. "I wound up selling off various pieces of the car and was left with the shell and the original tires and wheels. When the Gremlin had been in my garage for over 10 years, I decided the project wasn't going anywhere. As a long shot, I put an ad in the paper. Ron was my only caller," says Landino.

ARCHIVAL PHOTO

The Gremlin in 1970 with the team that turned it into a hybrid vehicle.

Enamait says he spent a year taking the car apart. When a job opportunity in Florida came along in 1990, the WPI Hybrid went along in the back of a U-Haul truck.

"When I got to Florida, I had a whole garage full of Gremlin parts, some from the 1970 car and some from a 1976 Gremlin I had acquired. The problem with the WPI car was that the cowl was really ruined during the conversion for the race and the roof was caved in. I started bringing parts of the two cars together to create one whole car. I bought a relatively expensive MIG welding outfit. My neighbor used to drop by every few days. He thought I was crazy. He just couldn't believe what I was starting with. However, I made a believer out of him after three or four months when something began to emerge that looked like a car again."

The July/August 1998 issue of *American Motoring*, the official publication of the American Motors Owners Association, featured a two-page article by Enamait on the resurrection of the former WPI Electric Hybrid from a first-prize-winning clean air racer in 1970 to the 650-horsepower "road rocket" show car it is today.

True performance-car buffs should appreciate this quote from the article that describes the changes under the Gremlin's hood: "The power plant was treated to a number of internal and bolt-on upgrades. Forged pistons, reworked 10.2 compression cylinder heads, Hooker Super Competition headers, a high-performance camshaft with Crane 1.7 ratio roller rocker arms, MSD ignition, a 250-HP nitrous oxide kit, an 800-cfm Holley double pumper carburetor, and a host of other 'enhancements.' The six-speed Richmond Gear transmission was the single most expensive upgrade and it generates the most interest and discussion at the local car shows."

"*American Motoring* publishes a lot of human interest stories about AMC cars and drivers," says Enamait. "So when I started pulling material together for the article, I decided I should find out more about the past of this car. As I was going through my wallet one day, I ran across the card on which I had written Paul's name and telephone number years before."

The two talked about the car on the phone and Landino gave Enamait the number of WPI's archivist, Lora Brueck, who sent him information about the 1970 race. "It really was an amazing event," he says. "It was particularly interesting to read about all the companies that contributed to the building of the WPI entries for the race.

"I work about 40 miles from my home and I drive the Gremlin to my office about twice a year," he says. "The mileage isn't very good. It probably gets 7 to 8 miles per gallon and I have to burn race fuel, which is 115 octane—that's $4 a gallon. So I don't drive it around town much. I usually trailer it when I go to shows.

"Every once in a while, I get the urge to take it into town, just for fun," says the "new" Gremlin's proud owner. "When I first put the car together, people thought I was a little bit crazy. Maybe I was. But right now, I can't go anywhere without drawing a crowd."

—Perry, longtime director of public relations at WPI, is now senior writer for Quest, *WPI's development newsletter. His efforts to publicize WPI's entries in the Clean Air Car Race won the University the coveted Silver Anvil Award from the Public Relations Society of America.*

◆ Award-winning Washout ◆ Tales From the Valley ◆ Glee Club's 125th

WPI JOURNAL

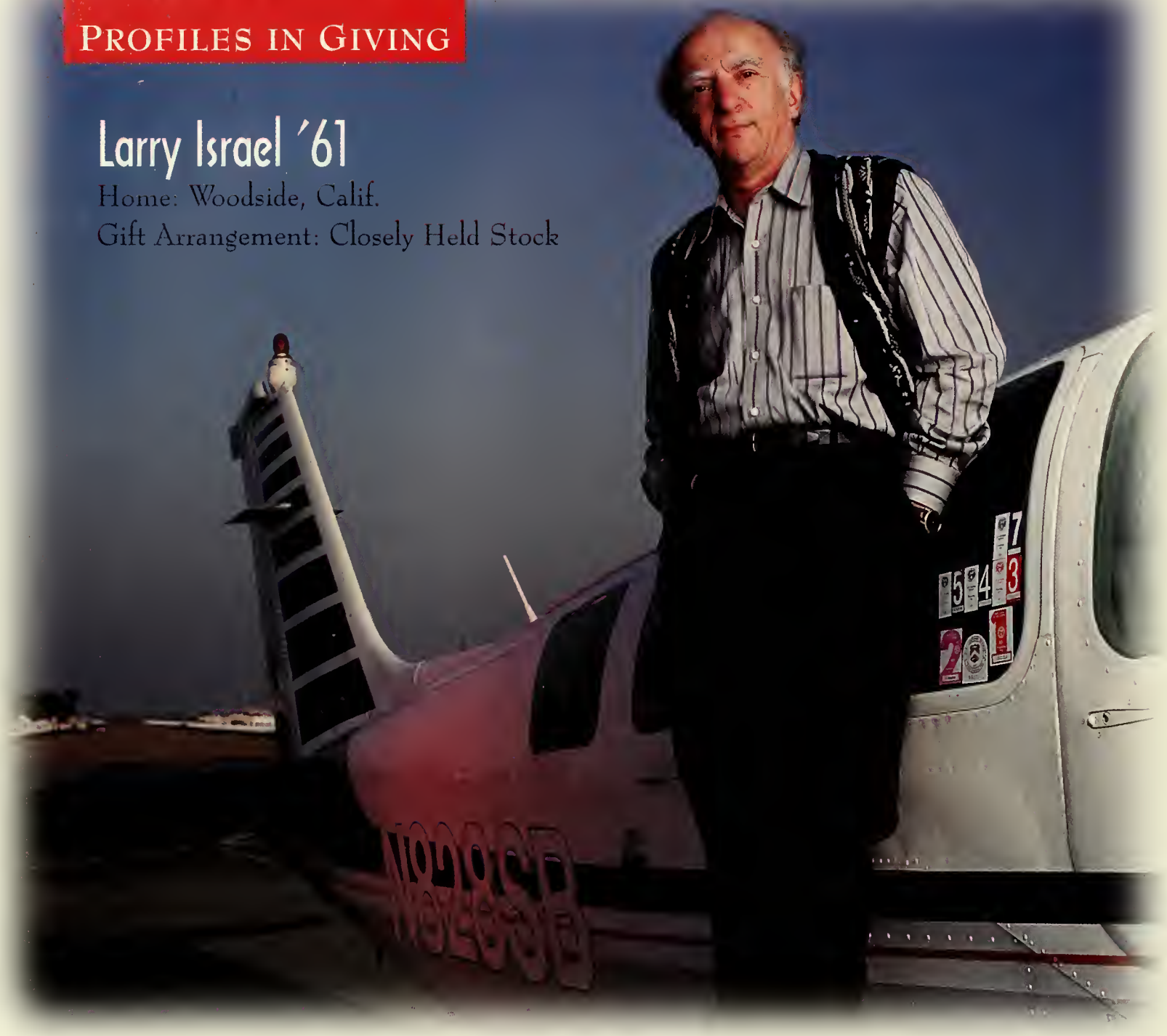
SPRING 2000

The Metal Processing Industries Cast Their Lot With WPI

PROFILES IN GIVING

Larry Israel '61

Home: Woodside, Calif.
Gift Arrangement: Closely Held Stock



— On Life's Passages —

"Life really started for me in my early 40s when I took up flying and gained a new sense of freedom, exploration and adventure," Larry Israel says. "I've flown all over North America and hope to fly to Europe and back soon." His professional life has also been a series of passages. After working as an engineer and earning a law degree, he co-founded VTEK, which marketed products to help the visually impaired read, write and type. When TeleSensory acquired the firm in 1989, Larry retired, but returned four years later as president and CEO of the firm. He retired again in 1999. But ever ready for a new passage, he has joined his wife, Diana, in running her furniture company, Mode Office Systems. "Nearly four decades after graduation, it's intriguing to get involved in a whole new industry and learn how it functions," he says. "But if WPI taught me anything, it's how to learn."

— On Gift Planning at WPI —

"I've long appreciated what WPI did for me, so I've tried to help it in any way I can," Israel says. He's been a class agent and a member of the Biomedical Engineering Advisory Board and his 40th Anniversary Gift Steering Committee. He's a Presidential Founder, an Alden Society charter member and a longtime member of the President's Advisory Council. He's also an advocate of giving closely held stock. "Private stock is not a useful commodity. You can't redeem it because it's treated as dividend income, so you either sell your company or hold the stock until you die. While some charities are reluctant to accept private stock, WPI takes a long-range view. With this kind of gift to WPI, I also get the benefit of an appraised value deduction without any cash outlay, so it's a win-win situation, as any good gift should be."

If you hold C-corporation or Subchapter S-corporation stock and would like to explore charitable giving opportunities at WPI, please contact Liz Siladi, director of planned giving, at 1-888-WPI-GIFT. All inquiries are strictly confidential.

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Front Cover: Strong, lightweight and easy to recycle, aluminum is becoming the metal of choice for a host of applications, particularly the manufacture of cars and trucks. For industries that make, process and use aluminum, WPI's Metal Processing Institute is the place to go for fundamental research. Story on page 4. Photo by Patrick O'Connor. Back Cover: Gleaming towers rise above Worcester's Union Station for the first time in more than 70 years, one of the most visible results of a $43 million restoration that turned a crumbling shell of a building into an architectural gem once again. Story on page 12. Photo by Dennis Vandal.

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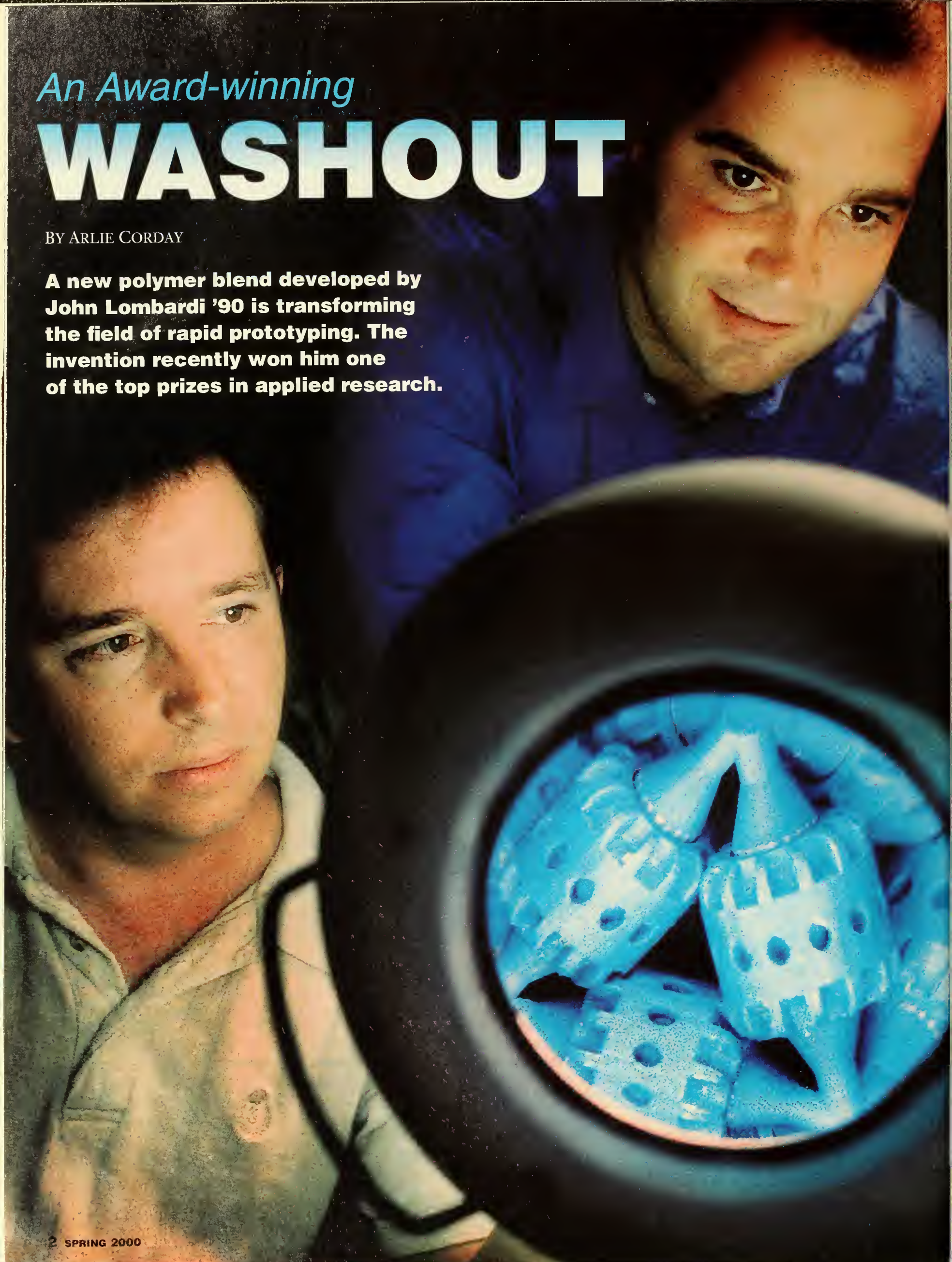
An Award-winning

WASHOUT

BY ARLIE CORDAY

A new polymer blend developed by John Lombardi '90 is transforming the field of rapid prototyping. The invention recently won him one of the top prizes in applied research.



Most inventors would be dejected if the product of their hard work and inspiration went down the drain. But John L. Lombardi '90 is all smiles. The new support material he invented, which washes away with warm tap water, not only revolutionized the field of rapid prototyping, but won the young chemist what's been called the "Nobel Prize of applied research."

Lombardi received an R&D 100 Award from *R&D Magazine* in September 1999. Each year the magazine gives the award for the top 100 new products. Previous winning technologies include the automated-teller machine, antilock brakes, the liquid crystal display, the fax machine, the touch-sensitive screen and the anticancer drug Taxol.

Lombardi won for the invention of Aqua-Port, a blend of polymers—a sort of organic alloy—that can do what no other rapid-prototyping support material can. Rapid prototyping is a method of translating computer-generated designs for new objects or parts directly into three-dimensional structures. Unlike conventional subtractive manufacturing processes (such as CNC milling), which cut parts from bulk feedstock, rapid-prototyping machines take the digital information and build up objects, layer by layer, from plastic, ceramics or wax. To prevent the layers from slumping, the growing parts generally are reinforced with a supporting material.

Until now, the supporting material often had to be carefully chipped away with dental picks or tweezers to reveal the prototype, a time-consuming process that also entailed the risk of damaging the finished piece or inadvertently removing fine details. But work by Lombardi, senior research scientist at Advanced Ceramics Research of Tucson, Ariz., and senior research technician Gregory Artz changed all that. Their discovery is a water-soluble support material.

"Instead of labor-intensive work, this new polymer blend can simply be washed from the part," Lombardi says. "All you need is a bucket of tap water, and 10 to 15 minutes later, you're done."

The process has a number of important advantages over previous rapid-prototyping technologies, he adds. For example, it can reproduce more complex geometries, generating parts that were previously impossible to prototype. The material can also support prototypes with internal cavities and tortuous channels, spaces from which it is virtually impossible to remove other support materials. The material is nontoxic and environmentally friendly, and it has high thermal stability, withstanding temperatures of over 550°F.

"It opens up a whole new way of manufacturing," Lombardi says. "Most water soluble polymers don't exhibit high thermal stability and cannot be used in most rapid-prototyping processes."

Lombardi, a Worcester native, received a bachelor's degree in chemistry from WPI. As a student, he was a summer research intern at Norton/TRW Ceramics Co. in Northboro, Mass. While there, he and research scientist William S. Coblenz '70 became good friends.

After graduation, Lombardi pursued a master's and a Ph.D. in materials science and engineering at the University of Arizona. While still a graduate student, he founded J.L. Lombardi & Associates, a materials processing consulting firm in Tucson. One of his three clients was Advanced Ceramics Research. Among a number of other projects completed for the firm over a six-year period, he was a principal participant in several research programs on polymer and ceramic free-forming funded through DARPA (Defense Advanced Research Projects Agency) and NASA Small Business Innovation Research (SBIR) programs. He is listed as co-inventor on several patent applications filed based on this work. He holds eight foreign and domestic patents, altogether.

After receiving his doctorate in 1996, Lombardi joined Advanced Ceramics Research as a full-time employee, where, among other assignments, he has been responsible for developing new ceramic processing technologies under contract from DARPA, a project that involved researchers at Stanford and Carnegie Mellon universities. He is also co-inventor of several commercial superfinishing products used in the planarization of semiconductors and computer hard disks. Overall, he has been responsible for products that account for $7 million in yearly sales for the company.

But the most commercially significant product he has developed is Aqua-Port. Funding for the invention came from DARPA, which is responsible for developing "the really high-end defense research technology that is critical to the future and defense of the United States," Lombardi notes. In an interesting twist, the person responsible for approving the funding for the research was William Coblenz, who'd left Norton by then to become a program monitor at DARPA.

Lombardi says his doctoral advisor at the University of Arizona, Paul Calvert, professor of materials science and engineering, provided assistance in the development of Aqua-Port. His collaboration with graduate students at the university, where Lombardi serves as an adjunct research professor, also played a role. He says his work with the students reminded him of the project work he did at WPI.

"WPI lets students see the broad spectrum of technology and its societal impact, and this invention follows that lead," he says. "With the help from our graduate students, I was reminded of the interdisciplinary aspect of a WPI education, which emphasizes how to define problems as well as how to be resourceful in their solution. That was an important part of what I learned at WPI.

"Now we've licensed this technology off to a major rapid-prototyping equipment manufacturer," he says. "These machines are used by all the major auto makers, for example, for the fabrication of design prototypes. This is really a good example of what applied research should be."

In addition to the R&D 100 Award, Lombardi garnered a 1996 Inventor Award from NASA *Technology Briefs*, a 1995 Graduate Student Research Award from the Materials Research Society, and research fellowships from NASA and Courtaulds plc.

Lombardi says Aqua-Port has a bright future. Apparently, the same could be said for Lombardi himself and Advanced Ceramics Research.

—Corday is assistant director of media and community relations at WPI.

"Instead of labor-intensive work, this new polymer blend can simply be washed from the part. All you need is a bucket of tap water, and 10 to 15 minutes later, you're done."

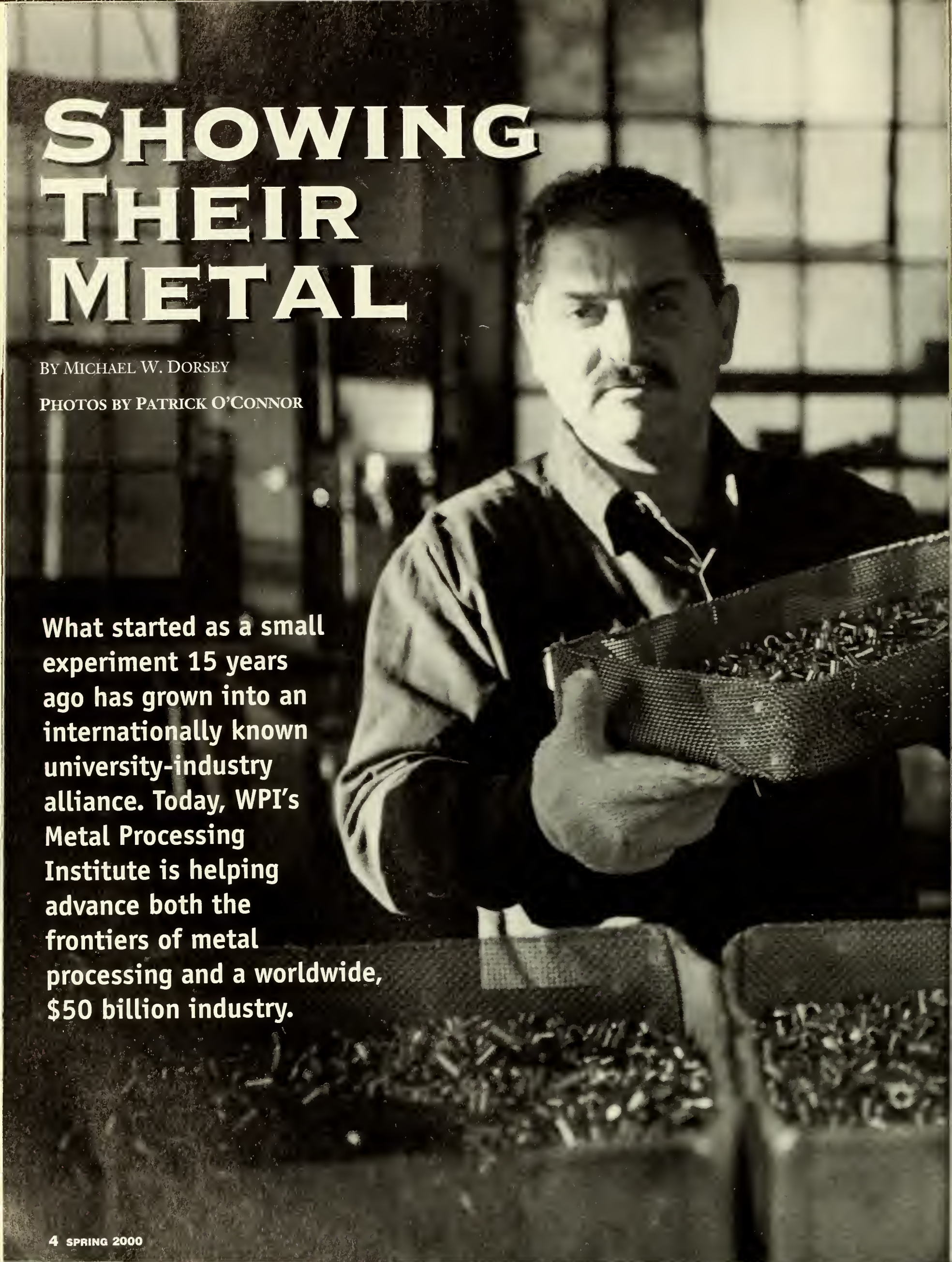
Lombardi, left, and Gregory Artz with a prototype made using Aqua-Port.

Showing Their Metal

By Michael W. Dorsey

Photos by Patrick O'Connor

What started as a small experiment 15 years ago has grown into an internationally known university-industry alliance. Today, WPI's Metal Processing Institute is helping advance both the frontiers of metal processing and a worldwide, $50 billion industry.



THE LARGEST INDUSTRY-UNIVERSITY ALLIANCE IN NORTH AMERICA began with an exchange of small talk over dinner one evening in 1984. Diran Apelian, then head of the materials engineering department at Drexel University, was attending a black-tie event to accept an award on behalf of his research team for the best paper published that year in *Metallurgical Transactions*. Beside him at the head table was the chairman of a major aluminum casting company.

"He said, 'You know, the casting industry, particularly the aluminum casting industry, has no educational home anywhere in America'," Apelian remembers. "'If I want to learn about new developments in aluminum casting, I don't know where to go.'"

The next morning, on a plane back to Philadelphia, Apelian drafted a letter inviting 10 aluminum casting firms to join a new consortium where, for $10,000 a year, they could support research and development and reap the benefits. "To this day, I don't know why I did that," Apelian says. "My laboratory was busy. We were flush with contracts from the Department of Defense, NASA, the NSF and other agencies. We didn't need the money.

"But I guess I'm an opportunist. I knew the industry was going to grow, and that these guys would need a link to academia. I decided to send that letter out and find out what would happen."

Three days later, an envelope was dropped onto Apelian's desk. Inside was a check for $10,000, signed by Ray H. Witt, chairman of CMI International Inc. (since acquired by Hayes-Lemmerz International Inc.)[1]. "I knew then we were on to something," Apelian says.

In all, 10 checks arrived, and the Aluminum Casting Research Laboratory was born. In the years since, Apelian's prediction has come true. The aluminum industries have, indeed, grown tremendously, as manufacturers have replaced more and more of the steel in cars, airplanes and other vehicles with aluminum to reduce weight and improve fuel economy, and as many new applications have been found for the lightweight metal.

The rising demand for aluminum products has led to growing competition among metal processing companies and increasing pressure to both improve the quality of finished parts and push the envelope in manufacturing technology. That, in turn, has placed a premium on fundamental and applied research on metal alloys and the various techniques used to fashion them into useful shapes.

Often unable to carry out this research on their own, companies that supply raw metal, form it into finished products, and use those products have turned to universities for help. Most have come to WPI, where the Aluminum Casting Research Laboratory moved in 1990 when Apelian became the University's provost. From its inaugural 10 members, the ACRL has grown to 35 companies. In more recent years, the ACRL paradigm has been used to establish industry-university alliances in other facets of the metal processing industry: powder metallurgy, semisolid metal processing and metal heat treating. Together, they comprise the Metal Processing Institute, which, with almost 140 members, dwarfs any other industry-university alliance in North America.

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In *The Graduate*, the young college grad played by Dustin Hoffman is pulled aside at a cocktail party and given some terse career advice. "Ben—I want to say one word to you—just one word—plastics."

MPI director Diran Apelian.

Diran Apelian has a similar scene in his life story, but for him the single life-changing word was "metallurgy." Born in Cairo, Egypt, of Armenian parents, Apelian came to the United States with his family at the age of 15. Speaking little English, he was enrolled in the 10th grade at Haverford High School in Haverford, Pa. Where others might have struggled, he thrived, becoming president of the student council in his senior year.

"My math teacher was fond of me," Apelian remembers. "I was interested in science and engineering, and one day I asked him what field I should go into. The Space Race had begun and he knew that America would be building a lot of rockets and would need new and better alloys. 'Metallurgy is where it's at,' he said. I didn't really know what that was, so I looked it up. It sounded fascinating."

Apelian enrolled at Drexel University with a major in metallurgical engineering. Taking full advantage of the university's co-op program and Pennsylvania's steel industry, he completed internships at U.S. Steel's Fairless Works, Techalloy and Ford Motor Co. One summer he worked as a National Science Foundation research fellow at the Franklin Institute, where he completed studies on pure beryllium.

"The 'Lehr und Kunst' model that we talk about a lot at WPI was something I really put into practice as an undergraduate," he says. "I was able to integrate the theory I learned at Drexel with practice. I think that had a very formative influence on me."

Apelian published the results of his work on beryllium and additional research in composite materials in Drexel's undergraduate research journal. He also edited *Alloy*, the newsletter of the university's Materials Engineering Department. With his bachelor's degree in hand, he moved on to MIT, where he earned a Sc.D. in materials science and engineering, working with Professor Merton Flemings, who would become his mentor and close friend. (Today, Flemings heads the Singapore-MIT Alliance.)

Rather than pursue an academic appointment, Apelian went to work in industry after completing his doctorate. He joined Bethlehem Steel's Homer Research Laboratories, where he helped develop the Ultra-Form Series, new high-strength, low-alloy steels that were featured (along with Apelian's photo) in Bethlehem's advertisements. Stronger than other steel alloys, they enabled auto makers to make thinner, lighter bumpers and other metal parts, reducing the weight of cars.

One day, Apelian received a call from the head of the Materials Engineering Department at Drexel asking if he could teach a course on thermodynamics for a professor who was taking a sabbatical leave. "I said, 'My God, that's the course I struggled with the most!'" Apelian remembers. "But I taught it, and I loved it. I then taught an undergraduate course, and that was even more fun."

Eventually, he took a six-month leave from Bethlehem to teach at Drexel. At the end of the term, he was called to the Dean's office. "I have a dilemma," Apelian remembers him saying. "We have an annual faculty teaching award. I pay attention to this award because the students select the winner.

[1]Witt recently renewed his commitment to aluminum casting research by endowing the Aluminum Casting Research Laboratory with a gift of $1 million.

You've won this thing hands down, and you're not even a full-time faculty member. How would you like to join us?"

"Of course, that went right to my head," Apelian says. "I accepted an offer for about half of my salary at Bethlehem. It was the best thing I ever did."

Apelian excelled as a teacher and a researcher. In his lab, he conducted pioneering work in various areas of solidification processing, including molten metal processing and filtration of metals, aluminum foundry engineering, plasma deposition, and spray casting. He did research in many of the areas that would later come under the umbrella of the Metal Processing Institute, including aluminum casting, powder metallurgy and heat treating. The work received significant support from the government and industry. Over time, it has also resulted in more than 300 published papers and a long list of awards and honors.

In 1983 he won an appointment as head of the Materials Engineering Department. It was while serving in that post that he launched the Aluminum Casting Research Laboratory. He would later go on to serve as associate dean of the College of Engineering and associate vice president for academic affairs and graduate studies. In 1990 he was recruited to become provost at WPI.

Having made a commitment to scale back his own research to concentrate on administering WPI's academic and research programs, Apelian recommended to the ACRL's membership that the center stay at Drexel. But after negotiations with the university failed to produce the level of commitment it felt was needed, the ACRL steering committee voted unanimously to move the center to WPI. Satya Shivkumar, who had worked as a postdoctoral student under Apelian at Drexel, was recruited to head the laboratory.

Molten aluminum is poured into molds in one of the facilities of the Aluminum Casting Research Laboratory, the first of the centers that later became the MPI.

Apelian served as provost for six years, presiding over a period that saw WPI grapple with a growing financial aid burden and other financial challenges. During his tenure, the University maintained strong enrollments despite a declining college-bound population and declining interest in engineering; expanded its global projects program; strengthened its diversity programs; nearly tripled its research funding; and won recognition for the first time as a national university.

In 1996 Apelian decided it was time for a change. He considered a number of senior academic positions at other universities, but ultimately decided to stay at WPI and devote his time to metal processing research and education. By then, the ACRL was the flagship laboratory of the Metal Processing Institute, which also encompassed the Powder Metallurgy Research Center (PMRC) and the Semisolid Metal Processing Center (SSMC).

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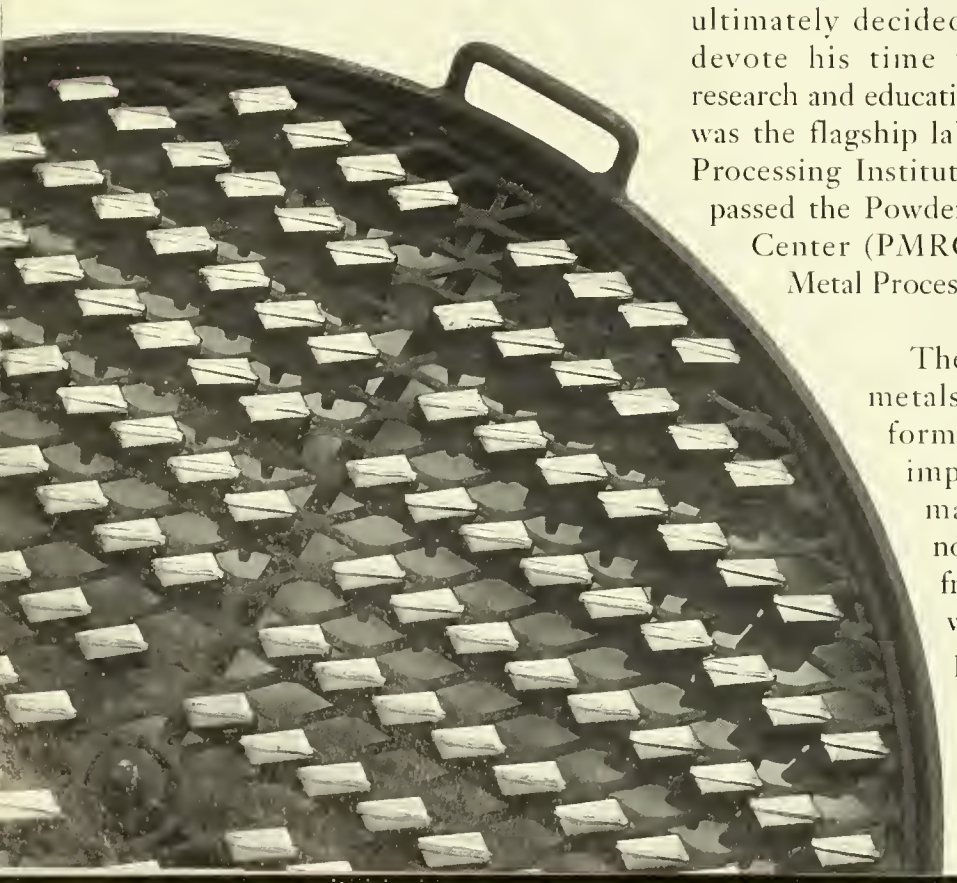

The process of extracting metals from their ores and forming them into useful implements is one of mankind's oldest technologies. Casting objects from bronze and copper was a well-established process in the Middle East as early as 3500 B.C. The use of iron to make tools and weapons followed about a thousand years later. Against this historical backdrop, the technology of aluminum processing seems like a Johnny-come-lately. The most abundant metal in the Earth's crust, aluminum was first identified as an element by Sir Humphrey Davy in 1808. It would take another half century to begin to develop solutions to the complex problem of extracting pure metal from the many materials, including bauxite, in which it is found in nature.

In 1885, world production of aluminum was just 15 tons. That figure rose to 8,000 tons by the turn of the century, increasing steadily to reach 680,000 tons just after World War II. The introduction of the aluminum beverage can in the 1960s accelerated the growth of the industry in the postwar years. In more recent times, rising fuel prices and the drive to build more fuel-efficient vehicles has placed a premium on the weight of cars and trucks. Since most of the weight of a typical vehicle is due to its metal frame, shell, axles, engine and drive train, finding ways to reduce the amount of metal in vehicles and replacing the steel traditionally used in cars and trucks with lighter metals has become a high priority for auto makers.

Aluminum, which provides up to a 55 percent weight savings over steel, but is also strong, rigid and easily recyclable, has been the alternative of choice. In fact, the use of aluminum in vehicles has doubled since 1991. The average car and truck produced today contains about 250 pounds of the metal, a figure expected to grow as much as 10 percent per year. Much of the aluminum in today's cars can be found in engine,

transmission and drive train components, though the metal is expected to one day replace steel in body panels and structural components, as well. The use of aluminum in vehicles has fueled a dramatic growth in aluminum production worldwide over the past few decades, and catalyzed a proportionate decline in steel production.

It was this strong upward trend in aluminum production, and the implications it held for the future of the aluminum industry, that set the stage for the Aluminum Casting Research Laboratory.

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Like all of the centers within the Metal Processing Institute, the ACRL puts most of its resources into precompetitive research—work that explores fundamental issues in aluminum casting of interest to all of the laboratory's members. Ideas for research projects come from the 35 member companies and are reviewed twice a year by a steering committee made up of representatives of member firms, who serve on a rotating basis.

"People in industry bring us their problems. They tell us about the things they cannot do today because of technological barriers," Apelian says. "They may not understand the physics of a particular process. They may not know what to measure, or they may be measuring things that are not important because the sensors that will measure more important things haven't been developed yet. However, in all of these problems, there is a fundamental scientific question that we try to define and subsequently solve. It's a different model for university researchers.

"In the old model, a researcher gets an idea and writes a proposal. Who needs his results? He doesn't know. How will they be used? He doesn't know. How will his research impact society? He doesn't know. Our mission is to educate and to create knowledge, but also to make useful contributions. To do that, we need to know what the problems and issues are."

Funds for the work of the ACRL (and the other MPI centers[2]) come from the $15,000 annual fee each member pays, as well as in-kind donations of time, manufacturing facilities, and aluminum ingots and castings. The ACRL is full of aluminum ingots and cast parts made of almost every aluminum alloy produced in the world. "I never have to buy aluminum," says Makhlouf Makhlouf, associate professor of mechanical engineering, who was named director of the ACRL in 1993.

The suite of research labs operated by the ACRL is overseen by Research Scientist Libo Wang.

The laboratory works on four projects at a time, each of which becomes the topic of a thesis or dissertation for a master's or Ph.D. candidate. The work is conducted in a suite of research facilities that are supervised by Research Scientist Libo Wang, who has been with the ACRL since its founding. The facilities include a casting lab and a separate analytical laboratory that has equipment for testing the mechanical properties of castings at a range of temperatures, and for testing fatigue strength and impact strength. The MPI also makes use of scanning and transmission electron microscopes, an X-ray diffraction laboratory and other material characterization facilities of WPI's Materials Science and Engineering Program.

One of the projects currently under way in the lab is examining the eutectic properties of aluminum alloys. When molten aluminum solidifies, jagged structures called dendrites, which are nearly pure aluminum, form first. The remaining material—a mixture of aluminum, silicon and other elements—forms in the spaces between the dendrites. "The material in the interdendritic spaces is known as the eutectic structure," Makhlouf says. "We want to know how and where it begins to form and how to control its formation. This will give us another degree of freedom as we design alloys for specific purposes."

A second project is looking at the feeding characteristic of aluminum, which is a way of measuring how quickly and smoothly the molten metal will fill the intricate details of a mold. "Some alloys flow nicely, and others do not," Makhlouf says. "We want to correlate these characteristics with the chemistry of the alloys. For example, will adding iron or magnesium produce better or worse feeding characteristics?

"Very little is known about this correlation, and yet this is fundamental information that companies can put to use immediately. For example, this knowledge may make it possible to make castings with thinner walls. If you have to make thick-walled castings just because you can't find an alloy with the right feeding characteristics, then you are unnecessarily increasing the weight of the part and the cost of your castings."

A third project is attempting to better understand—and identify ways to prevent—die soldering. After many cycles of heating and cooling, aluminum may begin reacting with the steel used to make aluminum casting dies.

(Continued on page 16)

[2]The newest MPI component, the Center for Heat Treating Excellence, has a three-tiered membership, with only the founding members—generally larger companies—paying a $25,000 fee; the fees are lower for the other membership categories.

True Tales from the VALLEY

While their fellow students back in Worcester were trudging to classes in the snow and bitter cold of another New England winter, several WPI undergraduates were enjoying the balmier climate of Northern California as C-Term got under way in January. But this was no fun-in-the-sun vacation—they were there to work. Specifically, they were there to plant WPI's flag in the high-tech mecca known as Silicon Valley and inaugurate the Silicon Valley Project Center (*The Wire*, December 1999).

The new center, directed by David Finkel, professor of computer science, is dedicated to work on Major Qualifying Projects in computer science and electrical and computer engineering. Like so many of the technology firms that dot the landscape in the Bay Area, the Silicon Valley Project Center is starting small with the promise of bigger and better things to come. Nine students went west in this first wave to work on projects for companies like Microbar in Sunnyvale and Kana Communications in Palo Alto.

The Silicon Valley Project Center was born in a series of meetings between WPI President Edward Alton Parrish, Provost John F. Carney III, other WPI administrators, and a number of alumni who are Valley veterans and who understand the tremendous potential for students to gain insights into the technology of tomorrow and the amazing, fast-paced, entrepreneurial culture that generates it by completing projects in the heart of one of the nation's technology centers.

WPI graduates are well represented among the pioneers, visionaries and innovators of the Valley. They have been involved in dozens of successful companies, from small start-ups to some of the biggest names in the computer and software industries. They continue to make advances and headlines, just as new graduates continue to be lured to the West Coast to be part of this forward-looking community and to stake a claim in a land where good ideas can be the seeds from which fortunes quickly grow.

A number of recent books have tried to capture the flavor of Silicon Valley and decipher its unique culture. One of the best-known chroniclers of life and work in the valley is Po Bronson, whose books include *Bombardiers* and *The First $20 Million Is Always the Hardest*. Among the young people Bronson profiles in his latest book, *The Nudist on the Late Shift*, is Scott Krause '94, who traveled to Silicon Valley in 1997. Alumni Editor Joan Killough-Miller caught up with Krause recently to find out what it was like to have his story told in a best-selling book and to see how real life in the Valley compares to Bronson's portrayal. To get a different perceptive on Silicon Valley, the *Journal* invited Greg Walsh '76, who has been working in the area for more than two decades, to offer his perspectives on the region. From his work at the legendary Xerox PARC laboratory to his recent founding of a new Web-based business, he has had his finger on the pulse of the changing technology and culture of this unique region.

Living the Dream

BY JOAN KILLOUGH-MILLER

As young people flocked to Silicon Valley in the "digital gold rush" of the late 1990s, journalist Po Bronson picked out a few recent arrivals to follow as they sought their fortunes in this land of high-tech opportunity. One was Scott Krause, now lead product manager at GO.com (formerly Infoseek) in San Francisco, a subsidiary of The Walt Disney Company. The ups and downs of Krause's first year in San Francisco are interwoven with the tales of five others in Bronson's book, *The Nudist on the Late Shift and Other True Tales of Silicon Valley* (Random House, 1999). An adapted version appeared in the July 1999 issue of *Wired* magazine, with Krause and some of his fellow newcomers on the cover.

Like many others of his generation, Krause went west to tap into the mother lode of Internet development. After graduating from WPI in 1994, he earned an M.B.A. at the University of Tennessee, then worked for a year in Knoxville, where he had the opportunity to manage a few Internet-related projects. "I felt I was touching the industry," he says, "but I wanted to fully immerse myself in it." In 1997 he headed to San Francisco, a city he had fallen in love with when he went there as a student to complete his IQP

(Continued on page 10)

SETH AFFOUMADO

Scott Krause was attracted to Silicon Valley by the chance to do meaningful work that may change the world.

Navigating the Peaks and Craters

BY GREG WALSH '76

Silicon Valley has entered the popular consciousness. That fact hit home with me last summer when I watched "Pirates of Silicon Valley," the story of Bill Gates and Steve Jobs, on TNT. In recent months we've been dot-com'ed to death on primetime TV. Books like Po Bronson's *The Nudist on the Late Shift* do a good job of describing the Valley's current frenzied activity, exposing the unfortunate shift from geek to greed. They also provide insight into its unusual culture. Activities that are quite normal here, like raising $3.5 million of venture capital money based on a few PowerPoint slides, must seem very strange to many outside of the Valley.

Silicon Valley has always been a special, dynamic place where new, trendsetting things happen. My first exposure to it and to the Internet occurred in 1973, during the summer of my sophomore year at WPI. Courtesy of MIT, Al Johannesen '67, then a young programmer in the Worcester Area College Computation Center (WACCC) and now WPI's managing senior UNIX administrator, and I got to upload and download files from the mythical SAIL (Stanford Artificial Intelligence Lab) at the then blindingly fast speed of 56 Kbits. This all happened over the primordial Internet, then called the ARPANET. At the time, the concept of distributed computing, running programs on another computer, and moving files around without using tapes or punched cards, was virtually unheard of. It was clear that cool things were going on out in California.

After graduating from WPI, I drove across the country to attend Stanford. There were already rumblings of the

(Continued on page 11)

SETH AFFOUMADO

Valley veterans Greg and Ruth Walsh find the region "a dynamic place where new, trendsetting things happen."

(Continued from page 9)
(Interactive Qualifying Project) with the Sierra Club. There, in the center of the West Coast's high-technology industry, he hoped to find work he really believed in.

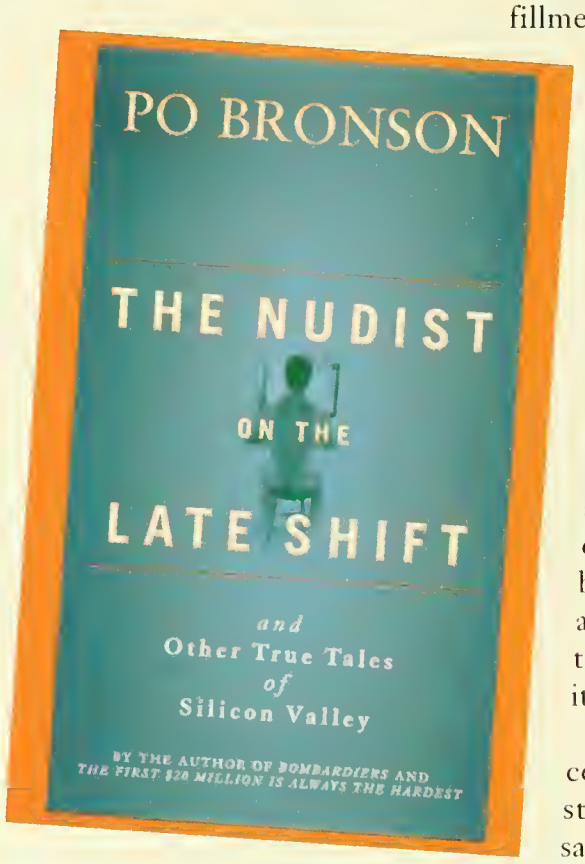
"It's still the first million I'm shooting for. To me, that's a little bit less important than the nature of my work, because out here it's almost assumed that you're going to get to that point some day anyway, so why worry about it."

As Krause weathered the frustrations and setbacks of his first year in Silicon Valley, Bronson watched and waited for his idealism to fade. It didn't. Even when Krause missed a big financial opportunity—his first employer, Intershop, announced that it was going public just after Krause left to pursue more meaningful work at Infoseek—he's still smiling, and talking about how much he likes his new job, and how his work will benefit humanity. In *Nudist*, Krause is pegged as a "modern-day Hardy Boy" with a "plain vanilla idealism" that Bronson associates with the heartland of America.

"I never thought of myself that way," says Krause with a laugh, "as the naíve, Midwestern type of person. Especially since I come from Massachusetts." Yet it is hard to talk with Scott Krause without wondering if he ever has a negative thought. "This is my dream job," he says. "I'm working for a leading company in a leading industry and I'm working on leading projects. It's pretty exciting. I think this may be one reason I came off as such a lofty idealist, but I really do believe that what we're doing for this industry is going to change the daily lives of people and how they work 10 years from now."

Another reason Krause's portrayal is so upbeat may be that a journalist friend warned him to be guarded about what he revealed. He says he was especially careful not to say anything negative about his employer. Others interviewed for *Nudist*—including the nudist himself—were up front about eccentric (and sometimes fraudulent or illegal) activities. Several requested anonymity in exchange for their stories.

Although he enjoyed his conversations with Bronson and the *Wired* photo shoot (as well as a supplementary interview and photo-op with the *London Observer*), Krause says the attention has hardly made him a celebrity. His notoriety did result in e-mail from long lost friends, and congratulations from higher-ups at his employer, but Krause has also had to endure a certain amount of teasing from his peers. Copies of the *Wired* cover appeared on office bulletin boards, adorned with Post-it® notes bearing comments from co-workers. Everyone expects "Hardy Boy Scott Krause" to live up to his image. "People would bust on me for leaving the office at 7:30—or even later," he reports. "They'd ask, 'What happened to those 70-hour weeks?'"



About the only complaint Scott Krause has about his life in Silicon Valley is the distance between him and his family and friends. He says he misses New England winters, although he still has strong memories of his last winter at WPI, when he would walk to campus from Bowdoin Street and pass cars that had been frozen under snow for months. "There's so much incentive for me to stay out here, from a career standpoint," he says. "I want to make the most of it while I'm here." Long-range, he would like to try working abroad for a few years, "but I would want to make sure that, by the time I move, there is a decent Internet industry in my destination."

Now that Infoseek has officially become GO.com, the fulfillment of The Walt Disney Company's promise to combine all of its Internet assets into a new business unit, Krause is excited about the opportunity to create new, unique products that integrate Infoseek's technology with Disney's content. He does worry that the company might lose its ability to innovate as is often the case with large bureaucracies. "If there's any reason I would leave, that would probably be it," he says.

Throughout his Silicon Valley saga, Krause stresses the value of job satisfaction over money—although he does not seem unhappy with the boost that the Disney alliance has given his present stock options. Is he any closer to the $20 million pot of gold that is portrayed as the standard reward for success in Santa Clara County? "I guess for me it's still the first million I'm shooting for," Krause laughs. "To me, that's a little bit less important than the nature of my work, because out here it's almost assumed that you're going to get to that point some day anyway, so why worry about it? Just have fun, and learn as much as you can along the way."

(Continued from page 9)
beginnings of the revolution. Xerox PARC, home of the Alto workstation, arguably the first true "personal" computer, was in full swing. I got a job there and ended up writing much of the "firmware" for the first WYSIWYG (what-you-see-is-what-you-get) word processor at Xerox. It really is true that much of what we know and love about personal computers was first conceptualized and realized at Xerox. The story of how the company missed the boat is well told elsewhere and is held up as a constant example of the consequences of slow moving, limited thinking.

Back in the Silicon Valley of the early 1980s, "fast moving" meant a product-development cycle of 18 months. That's an eternity on today's Internet time, but it wasn't really much time at all when developing a computer system meant building your own hardware, writing your own operating system, and developing your own applications.

Eccentric engineers laboring long hours under impossible deadlines were a fixture in the Valley then as they are now. More typical then were business-savvy types exploiting the fact that most technophiles are motivated not by monetary reward, but by the pure desire to engineer something and feel part of a winning team. There is a bit more knowledge today among new grads concerning the real risks and rewards of the Silicon Valley business world, at least among those who have read books like *Nudist*.

In my own case, life in Silicon Valley provided some valuable lessons about money and engineering. Contrast the value of a tiny equity position in a company with an initially silly sounding idea of a "single board computer upgrade" with the value of a much larger equity position in a company with an apparently well-thought-out and well-funded idea of a "graphics supercomputer." The former was Convergent Technologies, which set a record for the early 1980s for time-to-IPO and rapid growth rate. The latter was Ardent Computer, by some accounts one of the largest investment "craters" in the history of the Valley.

In 1995, Ruth and I were lucky enough to take a yearlong sabbatical from the Valley, courtesy of her role in setting up the customer support organization for yet another company that made it across the IPO finish line. Still not a big hit by Valley standards, it was big enough to enable us to take a break and regroup. We spent a year on a 42-foot sailboat visiting remote places in the South Pacific. A year later, when we stopped in the relatively civilized port of Papeete, Tahiti, and saw our first Pepsi can emblazoned with www.pepsi.com, we realized that new and possibly wonderful things were going on back home. Returning to San Francisco, we found that we had missed the entire browser wars, but were just in time for the rise of e-commerce and the expanding role of the Internet in business infrastructure.

After hooking up with three former associates who had also been both educated and chastened by previous successes and failures, and after producing the previously mentioned deck of PowerPoint slides, we set sail on a new venture, E.piphany Marketing Software. Three years later, on Sept. 22, 1999, in the final months of the 20th century, E.piphany joined the long and growing list of Silicon Valley success stories as the symbol EPNY was first listed on the NASDAQ.

"There is a bit more knowledge today among new grads about the real risks and rewards of the Silicon Valley business world."

Greg Walsh was born in Long Branch, N.J., in 1955, the year after IBM introduced the first mass-produced computer, the 650, and the year before another IBM team developed the first high-level programming language, FORTRAN. He earned B.S. degrees in electrical engineering and computer science at WPI in 1976, as a member of the last class to enroll before the start of the WPI Plan. The following year, he received an M.S. in electrical engineering from Stanford. He stayed in northern California to launch a career that has included work in hardware design, microcode, operating systems, compilers, office applications and, most recently, Web-based enterprise software. In his 22 years there, he has been part of some of the successes and "craters" that can result from the fast-paced, high-stakes life in Silicon Valley.

He was an early software engineer for the failed Stardent, a merger of Massachusetts-based Stellar Computer and California-based Ardent Computer. He has also worked for three start-ups that have successfully gone public; they include E.piphany, which he co-founded and which issued its initial public offering in September 1999. Headquartered in San Mateo, E.piphany is the leading provider of tools for enterprise relationship management (ERM), which has been called the next big wave in enterprise software. E.piphany's products, which help companies identify, understand and build relationships with customers, is being used by such companies as Hewlett-Packard, DirectTV, Charles Schwab, Microsoft and Wells Fargo. The company's stock, which had an initial offering price of $16, rose 183.6 percent in its first day of trading.

The Walshes are a true Silicon Valley family. Greg's wife, Ruth, also a longtime Valley resident, has been involved with two successful software start-ups. Their son, Eric, who earned a degree in history at UCLA, has continued the family tradition and now sells enterprise software for GO.com. Greg and Ruth enjoy long-distance ocean sailing and have plans to circumnavigate the globe in a few years.

Rewriting A Poem in Stone

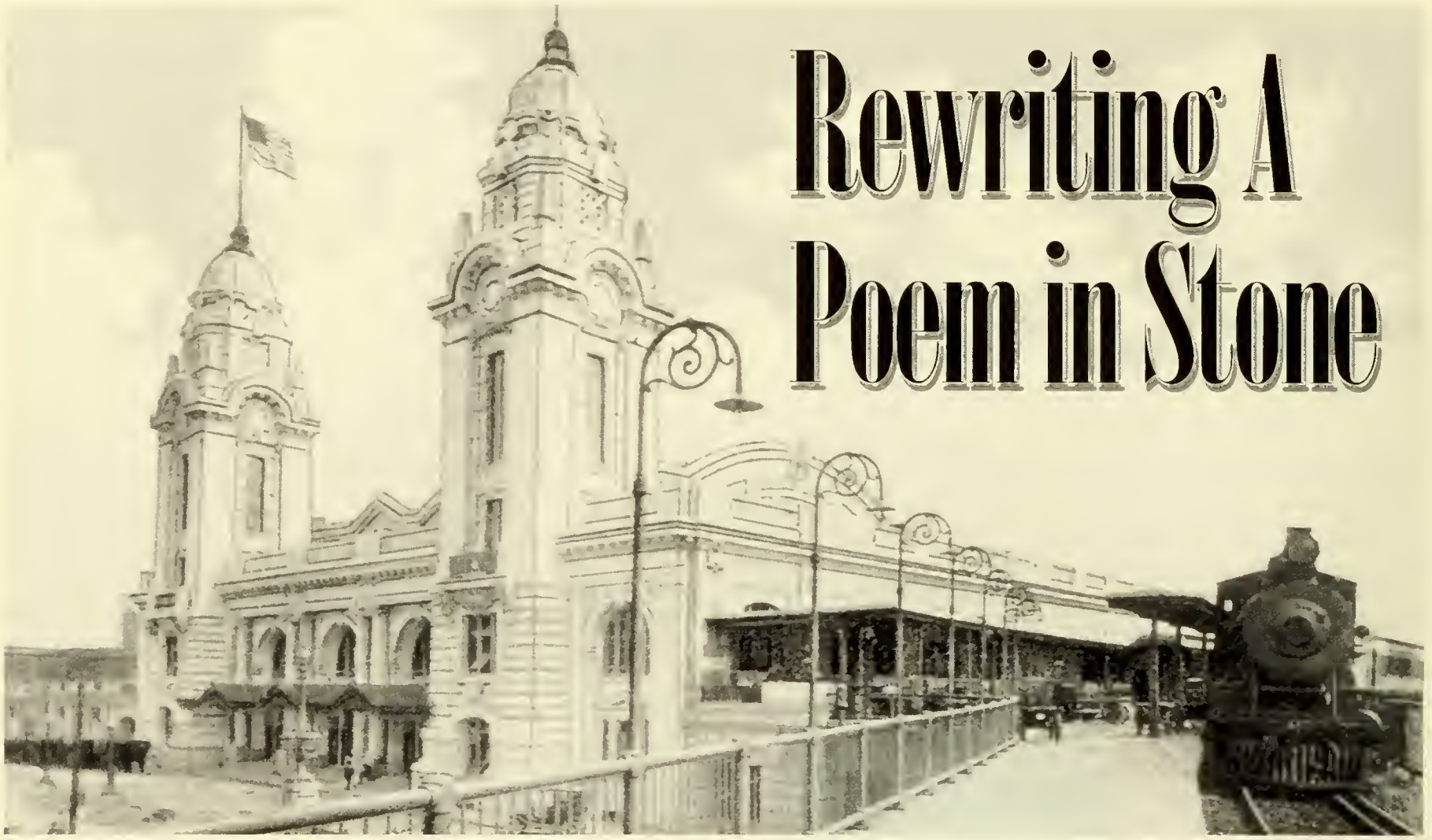


ILLUSTRATION COURTESY OF WORCESTER HISTORICAL MUSEUM

Three WPI alumni played central roles in the long-awaited renovation of Worcester's Union Station. Now complete, the beautifully restored transportation center has become a symbol of efforts to revitalize New England's second-largest city.

BY BONNIE GELBWASSER

The gateway to Worcester has reopened. Completed in 1911 at a cost of between $750,000 and $1 million, the city's Union Station was a transportation center that linked railway and streetcar service. Once called a "poem in stone," the 90,000-square-foot monolith in Washington Square was long considered one of New England's architectural treasures. It featured a terra cotta exterior with twin towers, stained glass windows, and ornate plasterwork.

Many immigrant families got their first glimpse of Worcester when they stepped off a train and into the grand concourse of Union Station. By 1917 there were 25 daily trains to Boston; 17 others traveled each day to Springfield and to other towns to the west. In the station's heyday, in the 1930s and 1940s, up to six million people passed through it each year on as many as 43 trains operated by three different railroads.

The growing popularity of the automobile in the years following World War II was the beginning of the end of the first chapter in the station's useful life. Intercity streetcar service ended in 1945; a decade later, the opening of the Massachusetts Turnpike enabled travelers to get to their destinations quickly, without the confines of the railroad timetables. The last passenger train departed Union Station in 1963; the last tenant, a barbershop, closed in 1976.

By the time the Worcester Redevelopment Authority purchased it in 1994, Union Station had been reduced to a ghostly shadow of the elegant building that once dominated the Worcester skyline. Deserted for more than 20 years and assaulted by vandals and the weather, the station was a crumbling, dingy shell facing the near certainty of the wrecking ball. The rescue and restoration of the building is one of the great triumphs in the ongoing revitalization of the downtown of New England's second largest city.

Three WPI alumni, **John H. McCabe '68**, chairman of the WRA board of directors, **Michael Latka '71**, executive director of the WRA, and **Cindy Blondin '92** (M.S.), the WRA's assistant director of engineering, have been instrumental in restoring the station to its former glory. In November, a grand ball celebrated the completion of the $24.8 million first phase of the project; Amtrak and MBTA (Massachusetts Bay Transit Authority) train service will begin operating later this year, shortly before the doors open to the community. In short order,

the WRA says, ridership is expected to climb to more than 1,000 passengers a day.

Union Station came to life again briefly during Worcester's First Night 2000. Thousands of revelers came to the station for the opening ceremonies at noon on Dec. 31 and stayed on to be entertained by musicians representing some of the city's more than 70 nationalities, who played late into the evening. Many returned to the station on New Year's Day for the Millennium Multicultural Community Festival of music, exhibits and dance, the culmination of this once-in-a-lifetime weekend.

McCabe, Latka and Blondin had good reason to cheer for the new year and for Union Station. They've spent much of the last two years working with regional, state and federal agencies to transform the facility into an attractive public building that will serve the city and the region well into the 21st century.

McCabe, a management major, is president of Automated Assemblies Corporation in Clinton, Mass. A former president of the WPI Alumni Association, he has received the John Boynton Young Alumni Award for professional achievement and the Herbert Taylor Alumni Award for Service to WPI. He joined the five-member WRA board nearly a decade ago. He says the board had three goals for the Union Station project. "Our primary goal was to achieve a historic restoration—to restore the original look of the building. The second goal was to create an intermodal transportation facility, and the third was to make Union Station a destination point for economic activity outside of the realm of transportation by attracting private developers to the building."

Latka holds a management degree from WPI and an M.B.A. from Western New England College and is a member of the Urban Land Institute, the American Institute of Certified Planners and the American Planning Association. He was assistant city manager for development and director of the city manager's Office of Planning and Community Development before being appointed to his current post in 1991.

"Union Station is the focal point of a $1 billion economic development effort that includes a medical complex, a convention center, an outlet mall, and the Massachusetts Turnpike/Route 146 connection projects," says Latka. "The city needs Union Station to strengthen the success of these projects, facilitate the movement of people in and out of downtown, and increase community activity and pride."

PHOTOS BY DENNIS VANDAL

As executive director of the Worcester Redevelopment Authority, Michael Latka has helped bring about two of the cornerstones of the city's revitalization: Union Station, seen here, and the new Worcester Medical Center.

As executive director, Latka works with a six-member staff, under the oversight of the board of directors, to identify and implement urban renewal plans within Worcester and to secure funding for them. In recent years his focus has been split between the four-year, $43 million Union Station restoration and the nearby $280 million Worcester Medical Center project.

Blondin completed her bachelor's degree in civil engineering at Southeastern Massachusetts University (now UMass Dartmouth) in 1983, then spent the next four years working for a contractor and taking courses toward her WPI master's degree in civil engineering. After receiving her Massachusetts construction

Cindy Blondin, the WRA's assistant director of engineering, says the complex renovation project employed a host of sophisticated materials and techniques.

supervisor's license, she moved on to a job with an engineering company. She completed her M.S. in 1992 and joined the WRA in 1993.

Federal and state funding in a ratio of 80/20 has supported the revitalization of Union Station, which is now on the National Register of Historic Buildings. Like the structure itself, the restoration efforts, which began in earnest in 1997, have been monumental. "Our first priority was to install a temporary roof in an effort to dry out the building," says Blondin. "We then brought in the general contractor, who made the building weather-tight to allow the subcontractors to begin work.

"The project has a design team of architects and structural, plumbing, electrical and mechanical engineers, plus a construction management team. There's also a general contractor with 20 subcontractors, such as painters, masons, electricians, plumbers, carpenters and cement finishers. I also work with the city, the Massachusetts Highway Department, the Department of Environmental Protection, and other state and federal agencies, and the Providence & Worcester and CSX railroads."

"The WRA board played an active role in managing what was a very difficult historic restoration," McCabe says. "Our responsibility was to be sure the project fell within its financial constraints. The results were borderline spectacular. There were fewer than 40 change orders, and they had the effect of less than 5 percent on the overall budget."

"A major project like Union Station or Worcester Medical Center requires you to utilize all of your academic and professional experience," says Latka. "Financial, engineering, planning and political skills are all stretched to the limit. But the satisfaction of restoring a historic structure or creating new opportunities for economic development where decadent and blighting influences have languished for years is indescribable. That defines public service for me."

Working out of WRA offices recently moved to the station, Blondin and Latka say they thrive in their jobs despite the pressures. "The project management components of my master's program have been important to my work," Blondin says. "At WPI, I learned about estimating, budgeting, reporting and contract law. Because I work with many consultants and contractors, it's imperative for me to understand contracts, which were the bases of my master's thesis. What I learned about scheduling has also been quite useful. Union Station was a complicated restoration project with a specific completion date. We developed a schedule at the initial design stage that allowed us to budget funds and select accurate starting and completion dates for each of the construction components."

While restoration teams have been sensitive to the structure's architecture and history, they have looked toward its next 100 years by incorporating technologically advanced products and materials where appropriate. "We've used 'real' materials like marble in areas where people are likely to touch the walls, and the terrazzo flooring is consistent with the original floors," Blondin says.

The twin towers that graced the original station (they were removed in 1926 because they leaked and had been weakened by constant vibrations from moving trains) have been rebuilt. "We chose fiberglass panels for the exterior of the restored towers because they are stronger, lighter and more cost-effective than the original stone," she says. "That enabled us to stay within budget. Inside the building, some of the plaster has been replaced by fiber-reinforced gypsum that was cast into molds and applied to the walls and ceilings."

The WRA recently hired Finard & Company, a Burlington, Mass.-based commercial real estate firm, to develop and market the station and several adjacent parcels. Approximately 200,000 square feet of space is proposed for development into a retail and entertainment center.

Now that the first phase of the renewal is complete, Latka is concentrating on the financial partnership components of the complex form of historic tax credits through to the master developer agreement with Finard. Partnerships with the MBTA and Amtrak and leasing deals are in the works.

Blondin has shifted her focus to several related WRA projects, including a 500-car parking garage and a five-stall bus depot (scheduled to open late in 2002) that will be connected to the station via a corridor beneath the railroad viaduct.

"Union Station is situated on a rotary whose traffic pattern makes it difficult for pedestrians and vehicles to access the building safely," says Blondin. "We are currently in the design phase of a proposal to replace the rotary with a four-way 'signalized' intersection. When it is completed in 2001, the redesigned roadway will also free up space in front of the station for a plaza and two large development parcels."

In addition to their work with Union Station, Blondin and Latka have been involved in the planning phase of several WRA projects for older, industrial areas of the city and are overseeing the final phase of Worcester Medical Center, including construction of a 1,000-car public garage and environmental cleanup.

Developed by Tenet HealthSystem, Worcester Medical Center replaced Saint Vincent Hospital, which moved into the complex recently. The center includes a modern 299-bed acute care teaching hospital and over 180,000 square feet of physician office space. Outpatient offices are adjacent to inpatient beds to enable doctors to be available to all of their patients at any time, and traditional nursing stations will become small caregiver units to create a quieter, friendlier environment.

"This was a major undertaking that involved the aquisition of public property by eminent domain, preparing the property for development, and then selling it to a private developer," McCabe says. The focal point of the complex is a 19,000-square-foot atrium. With three glass-enclosed elevators, a waterfall, retail space and extensive landscaping, the atrium serves as a place for members of the entire community to meet and to attend special events.

Busy as she is, Blondin stays connected to WPI by serving as a sponsor to several Major Qualifying Projects. In a recent MQP, students analyzed the Providence & Worcester Railroad's viaduct and developed a plan to relocate the structure. "The WRA is now in the preliminary design phase of this project," says Blondin. "Some of the concepts the students came up with are being looked at by our design team." Other WPI projects have focused on the Union Station and Worcester Medical Center parking garages.

Blondin is building a satisfying career at the WRA. "I am proud to be part of the team that is bringing Union Station to life," she says. "Everyone who has seen the building is impressed with how beautiful it is. What most will never see is all the technology—the sophisticated materials and equipment—that will enable this landmark to shine as the city's transportation center well into the future."

What people *will* see in the restored Union Station, McCabe says, may be just as important. "For years after I-290 was constructed, people looked at the station, an icon in decay, and saw a symbol of Worcester. Many people thought that until the station was destroyed or rebuilt, we would never be able to change that image of the city. Now, when those new towers are lit up at night, the station will become a beacon for a revitalized Worcester, a landmark the city can be proud of once again."

PHOTOS BY DENNIS VANDAL

In 1987, when the top photo was taken, Union Station was falling apart, the victim of two decades of neglect and weather. Today, after a $43 million renovation project, the building has been restored to its former glory. In the near future, passengers will again pass through this grand concourse, ready to board trains bound for Boston and other destinations.

To make castings, aluminum is heated in open crucibles where it is subject to contamination. The ACRL's clean metals program is addressing this problem.

(Continued from page 7)

If molten metal sticks to the die, parts of the casting or pieces of the die itself can be lost. When this happens, casters must replace or repair the expensive dies. "When soldering begins to occur, you have to continually change pins and liners inside the die, which causes downtime for the casting machines," says Makhlouf, who notes that results of the research to date indicate that changes in alloy chemistry may avert the problem.

The fourth of the current projects is identifying ways to enhance the fatigue properties of aluminum cast components through control of microstructure. Aluminum components undergo cyclic loading (tension and compression) that can lead to fatigue. Graduate students in the ACRL have made significant contributions that will help develop processing technologies that improve the fatigue properties of cast components.

In addition to the projects suggested by the ACRL membership, the laboratory has, over the past eight years, received more than $3.8 million from the U.S. Department of Energy to conduct basic work in aluminum casting. "The DOE is very much interested in reducing the weight of automobiles," Makhlouf says. "It also recognizes that aluminum casting is more energy-efficient and cleaner than steel production."

While ACRL companies do not choose the topics for the DOE projects, Makhlouf says each addresses a problem of general concern to the industry. In addition, through donations of supplies, expertise, and the use of their manufacturing floors, the consortium members collectively help WPI meet its cost share requirement to receive DOE funds. "I estimate that the raw materials we've supplied to WPI for research, whether castings or other materials, are probably worth about $100,000," says Paul S. Kennedy '67, president and CEO of Kennedy Die Castings Inc. in Worcester. "But I'm sure we've gained back at least as much in learning."

In one two-year project, the laboratory conducted an exhaustive study that correlated the chemistry of 24 aluminum alloys, covering the entire range of compositions used in industry, with their microstructure and physical and mechanical properties. The project involved studies of 20,000 cast specimens prepared for the lab by Kennedy Die Castings. The result was the publication of a textbook by the North American Die Casting Association; the book has become an invaluable reference for aluminum casting companies. A similar project, which is relating the casting characteristics of die-casting alloys with their mechanical properties, is nearing completion. That database will be released on a searchable CD-ROM.

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To make an aluminum casting, solid metal ingots are heated to about 660 degrees centigrade and melted. Then the molten metal is poured from open crucibles into molds. At various points in this simple process, the metal can become contaminated with foreign gas or solid matter that can significantly detract from its performance and desirability. The problem of melt cleanliness is one of the most important barriers standing in the way of more widespread use of aluminum in automobiles, since porosity caused by gas bubbles and weak points caused by solid inclusions can make aluminum parts more prone to cracking and fatigue.

The ACRL is currently in the fourth year of a five-year project funded by the DOE aimed at better understanding how aluminum becomes contaminated, how contaminants can be detected and measured, how contamination can be avoided, and how dirty metal can be cleaned. The program has already yielded some significant breakthroughs.

For example, work by the ACRL has led to the standardization of a test, known as the reduced pressure test, commonly used in industry to detect hydrogen gas in molten aluminum. "The same company can do this test and come up with a different

"THE DOE IS VERY MUCH INTERESTED IN REDUCING THE WEIGHT OF AUTOMOBILES. IT ALSO RECOGNIZES THAT ALUMINUM CASTING IS MORE ENERGY-EFFICIENT AND CLEANER THAN STEEL PRODUCTION."

— ACRL Director Makhlouf Makhlouf

result each time," Makhlouf says. "Inconsistencies in results makes it impossible for one company to relate its findings to those of another company. We have developed a standard way of conducting the test that will produce consistent results. The American Foundryman's Society is recommending this approach to its members. We hope it will eventually become standard practice."

The problem of measuring solid inclusions has been solved through research in MPI's Nondestructive Evaluation Laboratory, headed by Reinhold Ludwig, professor of electrical and computer engineering. Sergey Makarov, visiting research professor in MPI, Ludwig and Apelian have developed a sensor that uses a combination of a strong electric current in the presence of a magnetic field to create what are known as Lorentz forces. These forces can act on particles as small as 10 microns in diameter and direct them toward optical sensors for recording and analysis.

WPI has licensed the patented process to Heraeus Electro-Nite Co. in Philadelphia, which is developing a commercial version of the sensor it hopes to bring to market in the near future. The sensor, which will be more sensitive and less expensive than other instruments currently used by industry, can be incorporated into a feedback loop that will enable casters to make real-time changes in their process (for example, adjusting the temperature of the melt or introducing chemical additives) to keep inclusions under control.

Ludwig says it may be possible to use the same technology not only to detect inclusions, but to separate them from the molten metal. "If we can apply strong enough Lorentz forces on these particles, it may be possible to direct them to a specific location and remove them from the melt. There is a lot of industrial interest in this. We are also exploring how we can use the same forces to remotely steer or mix a melt."

As part of the DOE-funded Clean Metals Project, the ACRL is looking at other technologies for removing inclusions from aluminum melts, including activated filters and methods for floating inclusions to the top of the melt. The latter can already be accomplished using a device called a rotary degasser, which injects an inert gas into the melt from a graphite rotor. Rising gas bubbles capture inclusions and float them to the top of the melt. Then, either the inclusions are skimmed off, or clean metal is drawn from the bottom of the melt.

> "THERE IS A LOT OF INDUSTRIAL INTEREST IN THIS."
>
> **— Nondestructive Evaluation Laboratory Director Reinhold Ludwig**

"People have been using this device for a long time, but nobody knows the optimum way of operating it," Makhlouf says. "It's all trial and error. We are attempting to get a better handle on what is really going on."

To address this deficiency, Ph.D. candidate M.D. Maniruzzaman has been developing a computer model of a rotary degasser, a complex program that must simulate the fluid dynamics of a two-phase (liquid and gas) turbulent flow, as well as model the collisions between the gas bubbles and inclusions. "The model is nearly done," Makhlouf says. "Next, we will begin 'what if' games. What if we change the speed of the rotors, the flow rate of the gas, or the design of rotor? How will that affect the success of the process, and can we come up with guidelines for its optimum operation?"

Rotary degassers, filters and sensors would not be needed at all if were possible to prevent inclusions and gas contamination in the first place. Researchers in the ACRL haven't discovered a method for doing that yet, but they have determined that two methods currently used in industry to reduce melt contamination don't work very well. "One important source of inclusions is oxygen in the air, which reacts with aluminum to produce aluminum oxides," Makhlouf says. "Continuous ladling of the aluminum mixes the inclusions into the molten metal. Companies have covered the melt with inert gases or with salt fluxes to keep oxygen out, but we have found that cover gases don't work, and we have not yet found a flux that doesn't have an adverse effect on the metal."

"It is this interdisciplinary approach to problem solving that makes MPI stand out in the field of research," Apelian says. "These examples point out the strength that emerges when different disciplines, in this case electrical, mechanical and materials engineering, are brought together to address fundamental technical and scientific issues."

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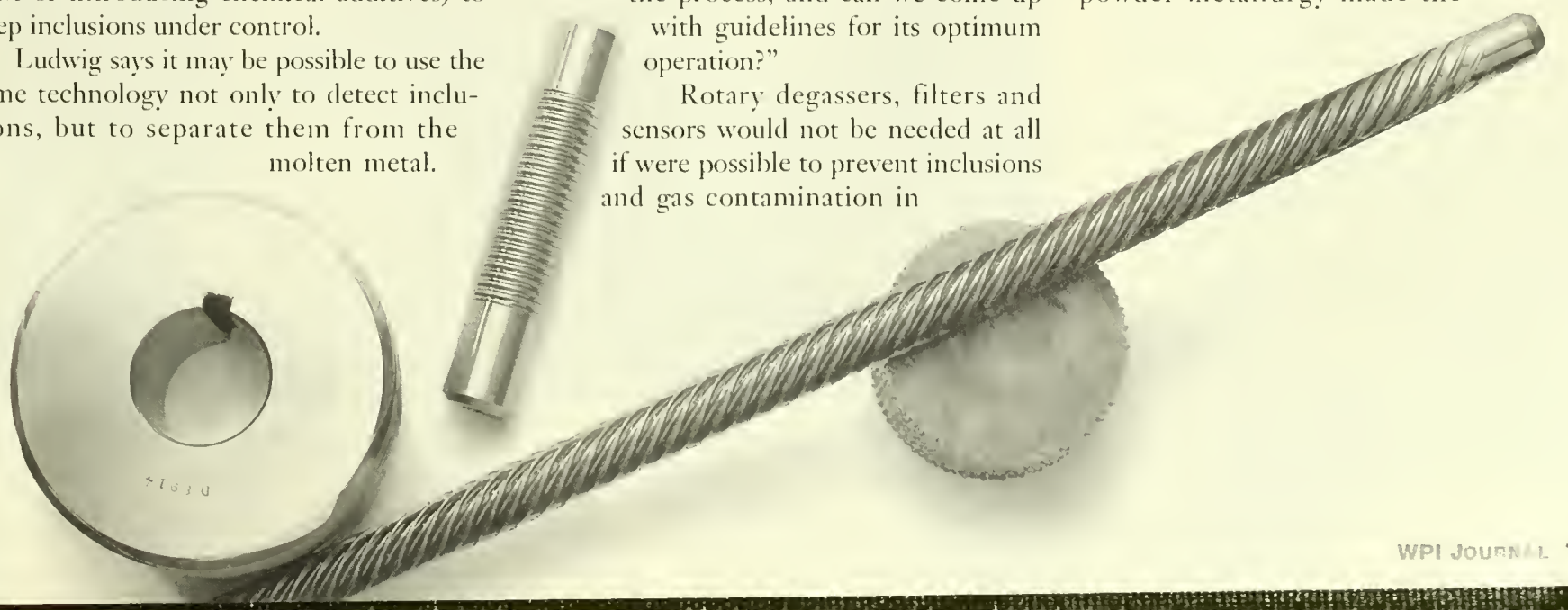
Though artisans may have been using metal powders to make jewelry and other artifacts even before the advent of metal casting, the modern powder metallurgy industry began in the 1920s, when the technology was first used to produce products like self-lubricating bearings and carbide cutting tools. Rather than molten metal, its raw ingredients are metal powders—mostly iron, steel and copper—which are produced by "atomizing" molten metal with high-pressure air or water. Mixed with lubricants, the powders are poured into molds and compressed under a force of about 50 tons per square inch. The resulting "green" compacts are heated in a furnace at a temperature below the melting point of the metal—a process called sintering—which fuses the powder particles.

The finished parts require virtually no machining and typically cost less to produce than comparable cast parts. The economies of powder metallurgy made the



process attractive to the rapidly growing automotive industry during the years following World War II, and auto makers now dominate the customer base for the industry, with about 70 percent of its output going into cars and trucks.

The Powder Metallurgy Research Center, the second component of MPI, was launched in 1991, with Ulf Gummeson as its first director. Gummeson, now executive director of the PMRC, studied mining and metallurgy in his native Sweden and

worked in powder metallurgy at Hoeganaes AB and Hoeganaes Corporation, where he rose to the rank of president by the time the firm was sold to American interests in 1968. He served as general manager of Nuclear Metals and president of New England High Carbon Wire Co. before rejoining Hoeganaes in 1978, He was president of the Metal Powder Industries Federation from 1987 to 1991, and received the organization's prestigious Powder Metallurgy Pioneer Award in 1996.

At its inception, the PMRC was given a two-pronged research agenda. One prong would have a technical focus—work aimed at better understanding and improving powder metallurgy itself. The other would have a management focus—work aimed at gaining insight into the workings of the P/M industry.

"This is an industry in transition," says Chickery Kasouf, associate professor of management. "We are seeing more and more consolidation and the emergence of large companies, but it remains a largely fragmented industry with many small firms, few if any of which have a large enough share of the market to affect industry outcomes. They are also stuck between large powder suppliers and large customers."

For the past eight years, Kasouf has been a principal investigator in a series of studies of powder metal parts producers. The series began with a four-round study, directed by Kasouf and former mechanical engineering professor David Zenger, with considerable assistance from Gummeson. "That study identified key management and engineering research issues in the industry," Kasouf says. "The results became the genesis of a proposal to the Alfred P. Sloan Foundation's Industry Studies Program."

With an initial round of support from the foundation, Kasouf, Zenger and Apelian conducted studies that looked at the relationships between parts producers, at the methods they use to estimate costs, at the increasing globalization of the industry, and at how P/M companies obtain and use information about their customers. Jacqueline Isaacs, assistant professor of mechanical, industrial and manufacturing engineering at Northeastern University and an affiliate assistant professor in the MPI, and Kevin G. Celuch, professor of marketing at Illinois State University, joined the research team partway through the first round. The Sloan Foundation has since funded a second round of studies (with Kasouf and Apelian as principal investigators and Isaacs and Celuch as co-investigators) that expand on these topics and also look at how electronic commerce is affecting the way parts producers interact with customers.

> "THIS IS AN INDUSTRY IN TRANSITION."
>
> **— Chickery Kasouf, associate professor of management**

The research funded by the first round of the Sloan award found that powder metal parts producers face several serious challenges. For instance, their customers are looking to them to provide more value-added engineering services, at the same time demanding even lower prices. In addition, parts producers often use inappropriate models for estimating their costs, which undervalue their own research and development work (for example, the expertise required to convert parts from cast iron or steel to powder metal). The problem becomes magnified over time, as customers expect regular price reductions after a contract is awarded. The globalization of the auto industry—with U.S. companies establishing overseas subsidiaries and foreign firms setting up plants in North America—have caused changes in the marketplace that may require new competitive strategies.

Overlaying these challenges, and hindering their solution, is the reluctance of parts makers to share information with each other or even with their customers, for fear of losing their competitive advantage. "It's a very wary industry," Kasouf says.

But the sharing of information can be a critical element in the development of positive buyer-seller relationships that increase competitive advantage and long-term success, he adds. For this reason, the factors that affect these relationships form a focus area in the second round of the Sloan study. "We are conducting a longitudinal study to

Marge Wood, manager of laboratories for the Metal Processing Institute, provides support for student and faculty researchers.

find out how firms manage their relationships over time," he says. "We want to know, for example, how they choose accounts, how they maintain a profitable business, and how they manage information flow."

In one study already completed, Kasouf and Celuch looked at the factors that determine how effectively companies gather and use information about their markets. Market intelligence, he notes, is an essential strategy in market-oriented companies, and market orientation is directly related to business performance and employee satisfaction. "We interviewed customers of parts producers and asked them how confident they are in their firm's ability to handle information," he says. "We found that a lot of information flow is driven by individual employees' perceptions of efficacy—in other words, how individual employees view their own ability to use information and how much they value that information. The good thing is that efficacy can be easily increased through good employee management."

Electronic commerce has opened new avenues for gathering information about customers' needs and business plans, but the powder metallurgy industry has approached this new medium with suspicion, Kasouf says. "The industry is concerned that using the Internet to exchange

Research on the processing of powder metals, bottom, under the direction of Mark Richman, is one focus of the Powder Metallurgy Research Center.

"A THOROUGH KNOWLEDGE OF CLIENTS' EXPECTATIONS, OBTAINED FROM MY RESEARCH, GAVE ME A BIG ADVANTAGE OVER OTHER CANDIDATES FOR MY JOB. IT NOT ONLY HELPED ME GET THE JOB, BUT EXCEL IN IT."

—Samyukta Warty, graduate student

information with customers will create an auction situation, where customers will expect parts producers to bid on each new part, enhancing the perception of their products as commodities. They would prefer a relationship where customers appreciate the value they add to products.

"The reality is, electronic commerce is inevitable. It's simply going to become a question of how the industry deals with it. In our future studies, we will look at how the industry can use the possibilities—the positives—of electronic commerce to its advantage."

Just as the research Kasouf and his team are conducting is helping the powder metallurgy industry adapt to changing times, it is also preparing students to thrive in the competitive world of industry, where an understanding of globalization, buyer-seller relationships and electronic commerce are vital tools. "It's really important to remember that it's not just PMRC members who benefit from this work," Kasouf says. "Students become immersed in critical industry issues."

Samyukta D. Warty, a graduate student who worked with Kasouf on the portion of the Sloan study focused on buyer-seller relationships, agrees. "My work helped me understand the supply chain management industry. As a result, I now have a job in a supply chain management company that works with buyers and sellers developing client-specific software for the e-business world. A thorough knowledge of clients' expectations, obtained from my research, gave me a big advantage over other candidates for the job. It not only helped me get the job, but excel in it."

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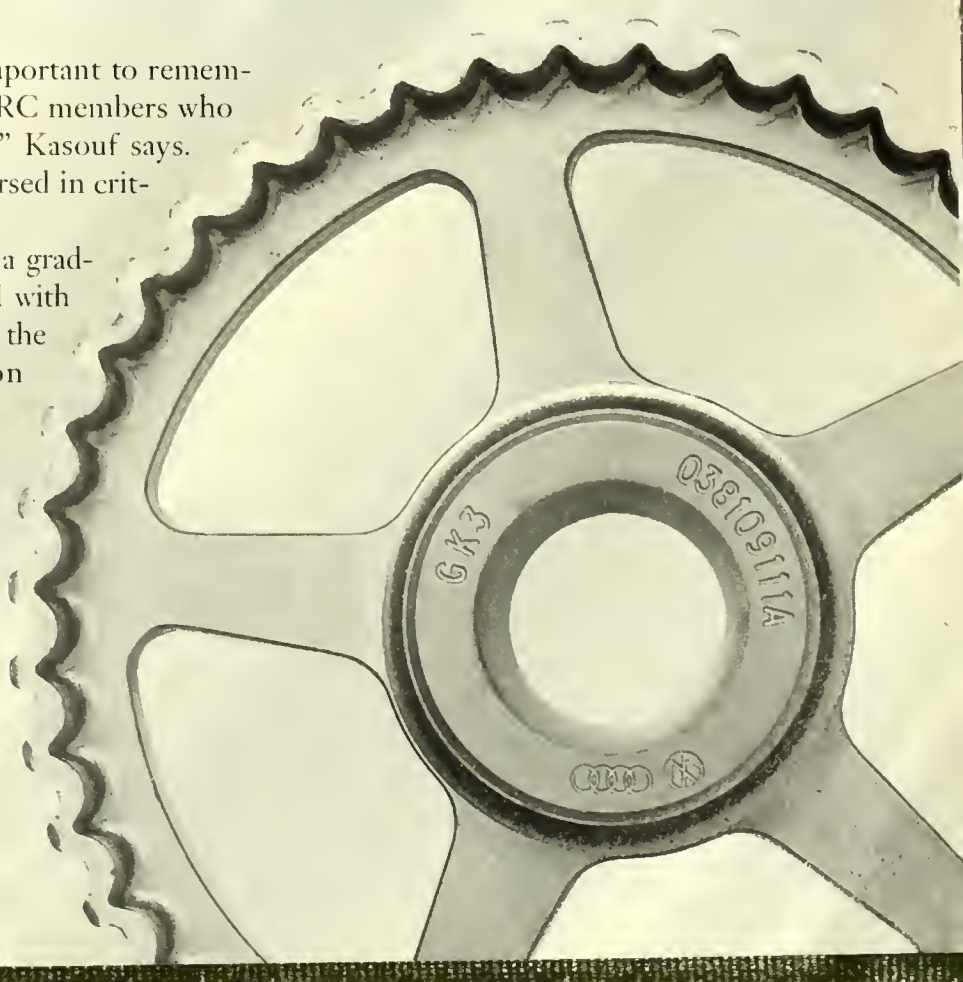
Like the other centers within the MPI, the Powder Metallurgy Research Center provides an opportunity for all sectors of the industry (from powder suppliers, to parts producers, to equipment manufacturers, to parts consumers) to support fundamental research that can benefit everyone—work that is often beyond the scope of any single corporate R&D department. Directed by Apelian and Mark Richman, associate professor of mechanical engineering, whose research interests include theories that govern rapid granular flows and models for the compaction of powder metals, the laboratory has conducted a variety of research projects on such topics as the densification of powder metal compacts and the delubrification of compacts during sintering.

Another line of research, conducted by Ludwig and the Nondestructive Evaluation Lab, has attacked a problem that PMRC members early on identified as one of the industry's most pressing needs—the ability to detect cracks before compacts are sintered. "Cracks typically occur early in the compaction process, due to press misalignment, blunt tools, and so on," Ludwig says. "You may create thousands of parts and



send them into the furnace for a typically long and costly sintering process, only to find out all are faulty due to one misaligned press. Therefore, the intent of our work has been to detect cracks in the green compact state, before it becomes too expensive to correct them."

The cracks in question are very small—as thin as 20 microns—and can occur on or under the surface of a part. Before Ludwig and his students accepted the challenge, no researchers had attempted to develop a system that would enable companies to detect cracks, trace them back to their source, and correct manufacturing errors—all in real time.

The team experimented with the use of eddy currents, ultrasound and X-rays without success, and then turned to electrostatics. Their solution, the product of four years of research and development, is a unique sensor that consists of hundreds of tiny needles. The needles are pressed against the compact and

current flow is initiated. The result is a voltage distribution that uniquely characterizes a good part. Deviations in the voltage pattern indicate the presence of a crack, which is instantly pinpointed by software developed by Ludwig's team.

"We have developed a test system where you take a compact coming out of the compaction press, place it in a mold and push a button," he says. "An arm driven by a stepper motor places the sensor against the part and the current is injected. The resulting voltage is analyzed by a PC, and either a red or a green light flashes, telling the press operator whether or not the part is flawed. The process fits in with the natural rhythm of the assembly line, so it is truly online testing."

With the encouragement of the PMRC membership, the technology has been licensed to a company that will soon deliver a beta version of a shop-floor system for several parts makers to test. When this system becomes available to the P/M industry, it will make an important contribution to its competitiveness, according to Ludwig. "Powder metallurgy is an inexpensive way to produce parts, so it has been attractive to end users," he says. "But at the same time, those end users have been applying pressure on parts producers to turn out flawless parts. Having the means to detect and eliminate cracks early on should help realize that goal."

■

Somewhere between the solid and molten states of metal alloys lies a class of materials with unusual properties. Called semisolid metals, they flow like liquids but can be handled like solids. Unlike pure metals, which have a single melting point, alloys melt over a range of temperatures. If they are heated to a point within that range and then stirred as they cool to break the long, tree-like dendrites that characterize semisolid alloys into small, round crystals, the result is a material resembling warm butter.

"A semisolid metal has some important advantages," says Andreas Alexandrou, professor of mechanical engineering and director of the Semisolid Metals Processing Center (SSMC). "Because it behaves like a solid, it can be picked up by a robot and moved around. But because it behaves like a liquid, it can be injected into a die, just like molten metal. As a semisolid material, it won't entrain gases, so porosity does not develop. Plus, because it is cast at lower temperatures than molten metal, it cools faster, there is less wear on the dies, and there is less shrinkage, so cycle times and maintenance are reduced, and dimensional tolerances are tighter. And finally, semisolid castings are superior to liquid castings and can be made thinner."

Not surprisingly, interest in semisolid aluminum casting is high, especially in the automotive industry. But, Alexandrou says, there is little fundamental knowledge about the process, which was developed at MIT just 25 years ago and placed in the public domain only within the past five years. In particular, he notes, commercial use of the process is limited by a lack of understanding of the complex rheology, or flow properties, of semisolid materials. "They don't flow like simple liquids," he notes. "Instead, they exhibit a highly non-Newtonian behavior."

The behavior of semisolid materials is further complicated, as they fall into a class of substances known as structured or thixotropic materials, which have internal microstructures that continually change as the material is processed. "Also," Alexandrou says, "the solid elements of these two-phase materials tend to stick together, creating what is known as yield stress. You have to exceed this stress before the material will flow.

"We are at a critical juncture where the future of this process will be decided," he adds. "Currently, there are only a few companies using this process, and the raw material tends to be expensive. But if technical, physical and economic issues are resolved, it has the potential to become a multibillion-dollar industry."

The SSMC is currently the only university laboratory in the United States conducting research in semisolid metals, and its approach to the problem is garnering the attention of researchers and corporations worldwide. With funding from the Department of Energy, Alexandrou has been developing sophisticated mathematical models of semisolid metals and their behavior when subjected to the stresses during casting.

The models are being verified by comparing the results with in-depth and painstaking experiments conducted at three

"WE ARE AT A CRITICAL JUNCTURE WHERE THE FUTURE OF THIS PROCESS WILL BE DECIDED. IF TECHNICAL, PHYSICAL AND ECONOMIC ISSUES ARE RESOLVED, IT HAS THE POTENTIAL TO BECOME A MULTIBILLION-DOLLAR INDUSTRY."

— SSMC Director Andreas Alexandrou

Seeking to become more innovative, the heat treating industry came to WPI to establish a research center.

locations: at WPI, by Apelian and his students; at Oak Ridge National Laboratory, by Srinath Viswanathan; and at MIT, under the direction of Merton C. Flemings, the inventor of the rheocasting process. The SSMC also has research relationships with universities in China, England, France, Germany and Russia, the most extensive of which is with the University of Aachen in Germany, where, in addition to intellectual exchanges, WPI undergraduate students have completed Major Qualifying Projects.

The ultimate goal is to develop computational tools that can be used to optimize the process and develop new alloys that are ideally suited for semisolid processing. Alexandrou says these computational tools could be used to analyze the way semisolid metal fills complex die shapes and to optimize conditions for high-quality parts. "We are at the forefront in the development of such models," he notes. "We helped create the model that is currently being used by such companies as Aluminum Pechiney, Volkswagen, Fiat, Yamaha and Hitachi."

The modeling of the unusual properties of semisolid metals was Alexandrou's entrée into the metal processing field. A mechanical engineer with expertise in fluid dynamics, he was the director of WPI's aerospace research group six years ago when he attended a faculty seminar given by Apelian that addressed the unanswered questions surrounding the use of semisolid metals. The presentation suggested to Alexandrou that the fluid flow models he and his students were developing at the time might hold the answers to some of those questions.

Alexandrou says working with the SSMC's 18 members has been a process of mutual education. As the member companies have come to appreciate the complexities of the semisolid metal process and the importance of mathematical models, Alexandrou and his students have learned about the realities of industry.

"We do work that is practical and theoretical at the same time," he says, "because industry doesn't often view things from a theoretical viewpoint, and universities don't always see things from a practical viewpoint. By talking with each other, we bring the discussion to exactly the right level."

■

"If you look at the literature from the 1890s up to the 1920s, you see that a lot of the work in metals and materials during that time was on heat treating," Apelian says. "After that, with the development of better microscopes, crystallography, X-rays and so on, it was possible to see inside the metal crystals, and the focus of the field changed. Today, the heat treating industry is realizing that it has not been as innovative as it needs to be. Just as the casting industry did 15 years ago, it went looking for an academic home."

After an extensive search of university research laboratories across the country, the heat treating industry turned to WPI. Having developed a new vision for the industry that placed a heavy emphasis on research and development, the American Society for Metals (with over 50,000 members) and the Metal Treating Institute (whose president is L. Thomas Benoit Jr. '66, president of Flame Treating and Engineering Co. in West Hartford, Conn.), approached WPI about establishing a center dedicated to research and education in heat treating. The Center for Heat Treating Excellence was inaugurated with a ribbon-cutting ceremony and symposium on Sept. 1, 1999. "With more than 60 member companies, this is the largest center in the MPI," Apelian says.

Initially, according to Apelian, the research projects for the new center will be conducted not just at WPI, but at other university and industry sites worldwide. Four major projects were launched in early 2000. The first, which focuses on the effects of microstructure and service properties on solution heat treatment of aluminum alloys, is being undertaken at the University of Connecticut. Another project, conducted by Yiming (Kevin) Rong, associate professor of mechanical engineering at WPI, is developing an analytical tool for part-load design and temperature control in loaded furnaces. The third is a major study of quenching during thermal processing; it is directed by Richard Sisson Jr., professor of mechanical engineering and interim ME department head at WPI. The fourth project, to be completed at Illinois Institute of Technology, is investigating the prediction of distortion and residual distress in heat-treated components.

As with the other centers in the MPI, the marriage between WPI and the heat treating industry was built on a fundamental principle of supply and demand. "Universities have two products," Apelian says, "the students we educate, and the knowledge that we create and disseminate. Companies need two things: innovation, and people who can implement the innovation. When you put those together, it's a no-brainer."

> "WITH MORE THAN 60 MEMBER COMPANIES, THIS IS THE LARGEST CENTER IN THE MPI."
>
> **— MPI Director Diran Apelian**

Apelian says member companies receive the innovation they seek from the MPI's research projects, the results of which are communicated to the members of each center during two annual workshops on campus (which also provide a forum for member companies to discuss issues facing their respective industries); through technical

seminars that address key problems each industry is encountering; and through technical education programs for interested members, including customized continuing education programs offered onsite.

Paul Kennedy says he has never had any doubts about the value of his company's membership in MPI. "Some of the best research in casting anywhere in the world is happening at WPI," he says. "Our membership gives us immediate access to that research, and enables us to drive it, as well. We've developed several new alloys as a result of research in the ACRL, and I know we would not have been able to do that had we not played a role in shaping that work. A lot of people think of casting as 'old technology,' but it isn't. It's really valuable for our people to see that and to get involved in the exciting things happening in the field. It helps them get out of the box."

As for the people side of the equation, Apelian says the activities of MPI produce a steady supply of men and women who are not only well-versed in the theory of metal processing, but who are familiar with the practical realities of putting that theory into practice in the commercial world—often through firsthand experience. "The real and true beneficiaries of everything we do are the students," he says. "Our faculty members, through their research, become much more aware of the issues facing the industrial sector. They integrate that understanding into their classroom instruction, so theory and practice comes forth in an integrated way."

Through Major Qualifying Projects and graduate research projects, students get a true taste of real-world engineering. "The undergraduates who complete MQPs through MPI typically complete a paid internship in industry the summer before they work on their project," he says. "They learn about industrial processes and they experience the corporate culture. When they come back to campus, they have a project topic and are ready to run with it. It's 'Lehr und Kunst' at its best."

At the graduate level, master's and Ph.D. candidates can get the same kind of firsthand experience by completing industrial internships. Students in this program spend half of their time in industry completing their thesis or dissertation work. "To use a business term, we 'outsource' the research," Apelian says. "There are many processes and types of equipment that we don't have at WPI, and in reality we don't want to have them here on campus because the technology changes every few years. Through this program, the facilities of industry become our laboratories."

Every year, four to six students take part in the program, each supported by about $40,000 per year from sponsoring companies. Another 20 students are supported through the fees member companies pay or through research grants from government and industry organizations. All benefit from the close contact they maintain with the members of the MPI's laboratories, who follow closely the progress of their research, and who prove attentive—and critical—audiences when they present their results.

"Each of our projects has a focus group of member companies," notes ACRL director Makhlouf. "They are in constant touch with the students. They get to know them well, and the students become quite familiar with the companies."

Three weeks before the biannual workshops, progress reports written by the students go out to member companies. "They read this stuff," Apelian says. "They bring the reports back to campus with all kinds of red marks. Then the students stand before this group of representatives from these leading companies (often including the vice presidents for research) and they make their presentations. I can't imagine a better experience. Knowing that what you are doing is important to somebody is an incredible incentive. We have a built-in motivation engine in the system."

> "SOME OF THE BEST RESEARCH IN CASTING ANYWHERE IN THE WORLD IS HAPPENING AT WPI. OUR MEMBERSHIP GIVES US IMMEDIATE ACCESS TO THAT RESEARCH, AND ENABLES US TO DRIVE IT, AS WELL."
>
> **— Paul Kennedy, President and CEO, Kennedy Die Castings Inc.**

Not surprisingly, students who've gone through this experience make especially attractive job candidates. "All of my students are hired almost the moment they finish," Makhlouf says. "And about 80 percent are hired by ACRL companies."

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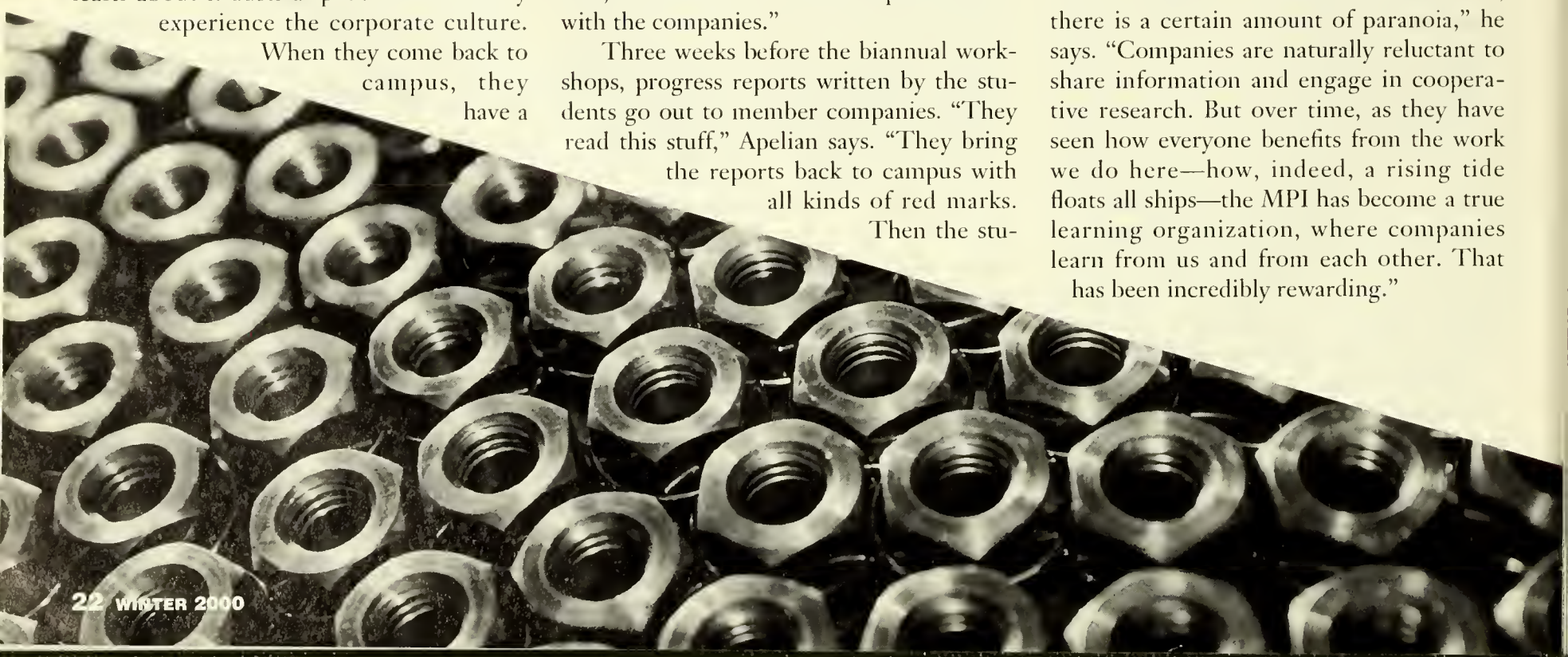
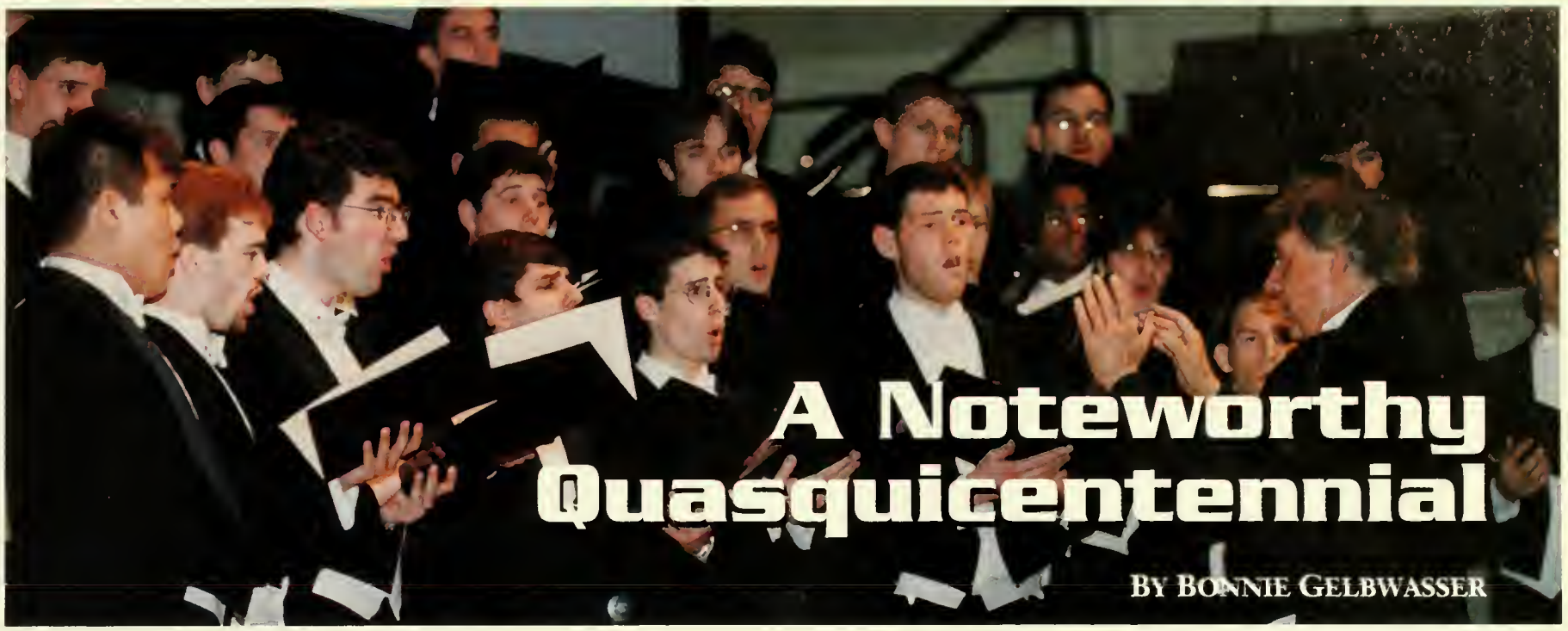
With the incorporation of the Center for Heat Treating Excellence and the growing maturity and international recognition of the other components of the MPI, Apelian has been taking time to think about how far things have come since he seized that opportunity more than 15 years ago. "We've built a strong organization," he says. "We've made some real advances in research and some fundamental contributions to near-net-shape manufacturing. We've prepared many talented men and women to make their own contributions to the field. And through all of this, we've gained incredible visibility for the MPI and for WPI."

But Apelian says the MPI's most rewarding product may well be the change it has brought about in the industries it serves. "When a center like this first starts, there is a certain amount of paranoia," he says. "Companies are naturally reluctant to share information and engage in cooperative research. But over time, as they have seen how everyone benefits from the work we do here—how, indeed, a rising tide floats all ships—the MPI has become a true learning organization, where companies learn from us and from each other. That has been incredibly rewarding."





A Noteworthy Quasquicentennial

BY BONNIE GELBWASSER

PHOTO BY JOHN GILLOOLY

The Glee Club helped WPI kick off its current capital campaign with a performance in Worcester's Mechanics Hall in April 1999.

The tuxedoed members of the WPI Glee Club may have to add "Happy Birthday" to their extensive repertoire this year. After all, it isn't every group that can boast 125 years of life.

The oldest student organization on campus has existed in some form since the spring of 1874, when nine members of the Class of 1876 came together as the Technical Glee Club to sing college songs. Disbanded and reorganized periodically during the next three decades, the organization was formally established as the Tech Glee Club in 1909. The group's 28 members practiced in Stratton Hall and charged 10 cents admission at their first concert.

. In succeeding years, the Glee Club performed in various venues around Central Massachusetts, from Worcester's Horticultural Hall to local schools and churches. On these trips the members occasionally had to call upon their engineering skills as well as their vocal talents, once repairing their truck when it broke down and another time wrestling an errant trolley car back onto the tracks.

The club performed its first radio concerts in the 1920s, when it also inaugurated joint concerts with the women of Wheaton College. During those years the men performed often with some of the newer WPI musical organizations, including the Tech Jazz Orchestra and the Boyntonians.

In 1932, Clifford Green, organist and choirmaster at Worcester's Unitarian Universalist Church, began a 27-year career as Glee Club director. During his tenure, the club expanded to more than 40 members, enlarged its repertoire, and increased the number of yearly concerts from a dozen to 30. Another organist/choirmaster, Henry Hokans of All Saints Church, succeeded Green in 1959.

Louis Curran assumed the Glee Club baton when he joined the faculty as WPI's first professor of music in 1966. Since then, he has led the group in local and collegiate exchange concerts and liturgical celebrations and directed performances on radio and TV. The choir still performs as many as 30 times a year, singing selections from a diverse repertoire that ranges from Mozart, Stravinsky and Schubert to more modern music. Its singing partners include choristers from Radcliffe, Regis, Smith, Wellesley, Wells, Wheaton and Wheelock.

Curran prepared the group for its first concert at Worcester Memorial Auditorium, where it performed with the Detroit Symphony, and shepherded the singers on their first tour to a distant venue, Washington, D.C., where they arrived during the fiery April 1968 weekend of Martin Luther King Jr.'s assassination. In 1977 Curran was on the podium when the singers performed J.S. Bach's Magnificat as the first choral group to open the newly restored Mechanics Hall. Since that time, the musicians have toured Austria, Belgium, the Czech Republic, France, England, Germany and Spain. They have released five recordings, including music commissioned specifically for the group.

Curran has an abundance of memories from his nearly 33 years as director. "On a tour to Rome," he says, "the Pope called us forward after the general audience. In Los Angeles, the women of Wheelock and the members of our club burst into *Saints Bound for Heaven* in the airport's rotunda, causing all movement to stop. And in Paris, the applause of some 2,000 people almost drowned out the great organ in Notre Dame Cathedral after we performed the music for High Mass and ended with Fenno's eight-part song *In That Great Gittin' Up Mornin'*."

Esteemed for its musicianship and professionalism during nearly all of its 125-year history, the Glee Club continues to accumulate accolades. After a recent performance with the Concord (Mass.) Orchestra of the 5th movement of the Busoni *Concerto for Piano, Orchestra and Men's Chorus*, *Boston Globe* reviewer Richard Dyer noted that the WPI men "pumped out sound of ringing quality in comprehensible German."

In 1999, the organization established the Clifford Green Award to be given for long-standing support of the Glee Club and created an endowment to support operational expenses, such as music, travel and guest soloists. "With the continuing support of Glee Club alumni, I think the endowment will be successful," says club president and baritone Tim Thies '00. "Response from alumni and friends has been enthusiastic," adds Theodore L. "Ted" Dysart '94, who is spearheading the initiative. "To date, we are near the halfway point of our $50,000 goal. I am confident that we will reach this goal with the support of alumni who want to help give future students the same opportunities that we all enjoyed during our college years."

Editor's Note: *Information about the early years of the Glee Club was taken from a Humanities Sufficiency completed by Paul Torcellini '86. For more information about the Glee Club, visit the club's Web site,* www.wpi.edu/~gleeclub.

The Fullest Possible Accounting

Jan. 24, 1973: *The New York Times* carries the headline "VIETNAM ACCORD IS REACHED; CEASE-FIRE BEGINS SATURDAY; P.O.W.'S TO BE FREE IN 60 DAYS." In a televised address, President Richard Nixon calls for "the fullest possible accounting for all of those who are missing in action."

March 30, 1973: The headline in the *Times* reads, "U.S. FORCES OUT OF VIETNAM; HANOI FREES THE LAST P.O.W." Within months, 591 U.S. prisoners of war will return under "Operation Homecoming." Nixon will tell the nation, "the day we have worked and prayed for has come."

But the story doesn't end there.

"Somewhere in America, the parents, spouses, siblings and children of 2,000 individuals wonder why their child, their helpmate, their brother or sister, or their parent never came home from the conflict in Vietnam," says Air Force Lt. Col. David Jacobs '81. Jacobs recently returned from Hanoi, where he spent a year as deputy commander of Detachment 2, Joint Task Force-Full Accounting (JTF-FA). His charge was to help plan and execute operations to make the fullest possible accounting of the fates of 2,600 Americans who were missing in Southeast Asia at end of the war. He also assisted JTF-FA's other detachments in Bangkok, Thailand, and Vientiane, Laos, which investigate unresolved cases in Cambodia and Laos.

Jacobs, who is well read on the controversy that has surrounded POW/MIA issues for decades, is straightforward when he speaks of the work under way in Hanoi. "We investigate reports of live sightings of conflict-era American citizens. We investigate priority cases of individuals who were last known alive in Vietnam immediately before the incident of loss. We recover the remains of individuals when we can locate their gravesites."

An investigation has two possible outcomes: "We either return a live American citizen, or we return identifiable remains." Government policy is to investigate all reports of live Americans being held in captivity, but according to the JTF-FA Fact Sheet, no "definitive evidence" has been found, other than reports that correlate with personnel whose fate was already known. Jacobs says, "Not since Operation Homecoming has an American returned alive who was held against his will.* So most of our efforts are on recovering identifiable remains."

The work of excavating crash and burial sites, often in remote and dangerous areas, is led by visiting teams of field specialists deployed from the Army's Central Identification Laboratory (CILHI) and JTF-FA Headquarters, both in Hawaii. During the monthlong missions, it was Jacobs' job to coordinate the messing and billeting of more than 700 individuals, including American military and civilian personnel, Vietnamese officials and local laborers. He arranged for their medical care, supplies, equipment and transportation, and he negotiated the access and compensation agreements with the Socialist Republic of Vietnam (SRV) that make the work possible.

** Several servicemen have returned alive from Southeast Asia since 1973. The government has judged them, and some others on the missing lists, to be military deserters or defectors who stayed behind by choice. Perhaps the most publicized case was that of former Marine Pfc. Robert R. Garwood, who was court-martialed in 1981 for collaborating with the enemy. POW/MIA activists contend that Garwood was falsely accused to discredit his claim that he and others were being held captive after Operation Homecoming concluded.*

"Our life revolves around the investigation and recovery teams," Jacobs wrote last year from his post in Hanoi. "We prepare for them. We do them. We recover from them. When the teams are in Vietnam, the commander and I work 16-, 18-, sometimes 20-hour days. We catch naps when we can. Either the commander or I visit the recovery sites at least weekly. When the teams leave town, we spend a week sleeping and doing the minimum tasks we absolutely must do. Then it's time to prepare for the next set of teams."

Case resolution is a lengthy process, which can include archival research and interviews with local people who may have reported a sighting or witnessed the original incident of loss. Once remains are found, anthropologists screen out animal bones and human remains that obviously belong to indigenous people. "We return two to nine sets of probable human remains believed to be those of U.S. citizens following each investigation and recovery period," says Jacobs, "and every one is important." The remains are sent to Honolulu for identification at the CILHI. Since 1973, more than 500 sets of remains have been identified and returned to next-of-kin.

Trading in human remains is illegal in Vietnam, but that doesn't stop dishonest citizens from raiding local graveyards and trying to collect an "honorarium" for turning in bones that they insist come from missing Americans. Jacobs met many of these criminals face to face while investigating their claims. One case that sticks in his mind involved a man who wanted to ensure he would be "reimbursed for his expenses" before he would turn over his findings. "This citizen's story was flaky, so we put the case on a back burner while we pursued higher probability cases," Jacobs recalls. "Eventually I took a team composed of an interpreter, a forensic anthropologist, and a representative

Opposite page, Jacobs wrings out his socks after a hike into the jungle. On that trip, Jacob's team confirmed the site of a downed U.S. military aircraft and recommended the site for excavation. Above, Jacobs, center, and the investigation and recovery team that located the aircraft wreckage, along with an old booby trap.

from the central government to visit this citizen. We met the province officials. We met the district officials. We met the village officials. Finally, we met the citizen.

"This citizen talked for a long time about the difficulties he encountered recovering these remains and the many sacrifices he made protecting them while he was waiting for us to inspect his find. Finally, he presented a single bone wrapped in toilet paper. The anthropologist took one look at the bone and pronounced it to be from a large animal, but not a human. When the village officials ordered the citizen to produce all the remains in his possession, the anthropologist took a few minutes and pronounced the remains all to be from a large animal, probably a pig.

"I've never seen anybody look that devastated. This citizen was built up for a big payoff, and his world came crashing down on him in a few minutes. It turns out pig bones are similar to human bones, and it takes an expert to discriminate between the two. There are many pigs in Southeast Asia, and we frequently were presented with pig bones."

Despite the sometimes harsh conditions, Jacobs found much to appreciate about the country that many Americans know only through the war. "Vietnam is strikingly beautiful," he says. " Much of the inland sections are triple-canopy rain forest. There is an unbelievable diversity of wildlife. Many of the beaches here are still pristine and undeveloped. Hanoi has two large beautiful lakes. Da Nang and Hue have more recreational activities, but the food is better in Ho Chi Minh City."

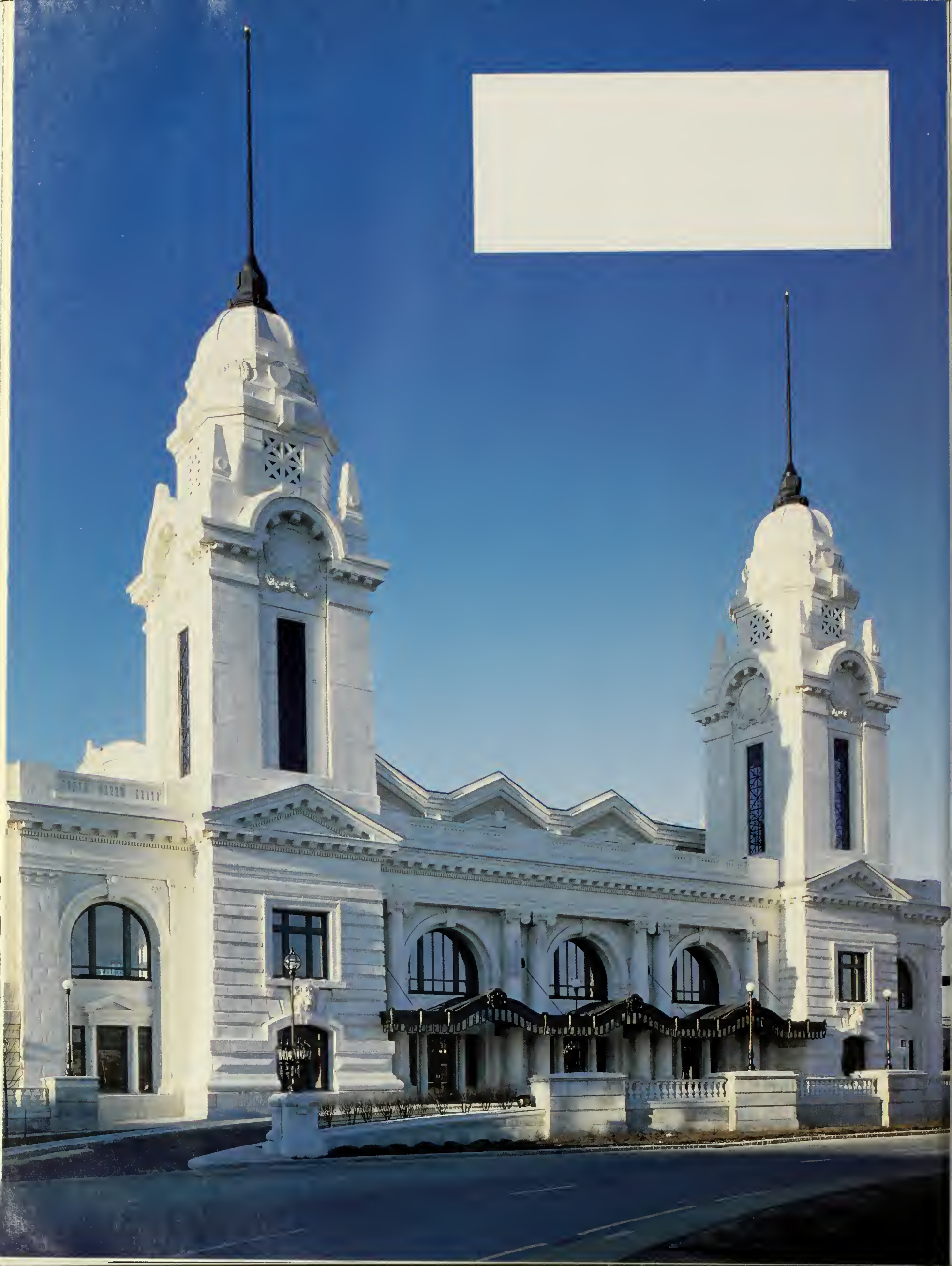
Apart from spending a year on a separate continent from his wife, Jacobs says the hardest thing was living in a communist country where a totalitarian police state exists. "Imagine George Orwell's *1984* mixed with Aldous Huxley's *Brave New World*, and you'll get a pretty good idea of life in Vietnam," he says. "The government here still believes it can control the economy. The government's control of the press is frightening." In the face of this repression, Jacobs admires the Vietnamese people for their resilience, generosity and honesty. "There are people who will share their meals with a stranger who looks lost, even if that stranger is an American," he says.

In December, Jacobs graduated from the Advanced Program Management Course at the Defense Systems Management College, located at Fort Belvoir in Virginia. He's since reported for duty as chief of the Transition Planning Cadre at the Air Armament Center at Kirtland Air Force Base in Albuquerque, N.M. "The cadre reconnoiters federal laboratories for directed energy technologies with weapon systems applications," he says, "helps to mature those technologies to the point where they can be transferred to acquisition programs at system program offices, and assists with the planning for the transition (ensuring personnel and funding are available to support the transition)."

Back in Hanoi, the work of recovery and repatriation goes on. In late August 1999, the Pentagon's Defense POW/Missing Personnel Office announced the identification of the remains of three soldiers, one of whom had been missing since 1966.

More than three decades after the Vietnam War, unresolved questions still trouble many Americans. Jacobs says a number of political and historical factors have complicated the situation. "The relationship between the governments of Vietnam and the United States has evolved from one of animosity in the 1970s, to suspicion and mistrust in the 1980s, to cooperation in the 1990s, to partnership today. Historically, the Johnson administration's foreign policy was kaleidoscopic, and the Nixon administration's fascination with secret plans exacerbated the problems.

"Another source of conflict is the different attitudes within the military services toward recovering human remains. For example, the sea services consider burial at sea to be a desirable and honorable burial, but the Army and Air Force have a tradition of never leaving comrades on the battlefield. And part of the problem is there are unscrupulous individuals in America who prey on the hopes and fears of the surviving family members."

Where will it all end? "Every president since Nixon said that obtaining the fullest possible accounting of the missing is a cornerstone of his foreign policy in Southeast Asia," says Jacobs. "At some point, the then-current administration and Congress will decide that the fullest possible accounting has been achieved. The President's ambassador to the government of Vietnam, Douglas 'Pete' Peterson, once said that a hundred years from now, there will be someone in the American Embassy in Hanoi who will continue to work to resolve these cases. Personally I think that decision is about five to 10 years down the road."

—JOAN KILLOUGH-MILLER